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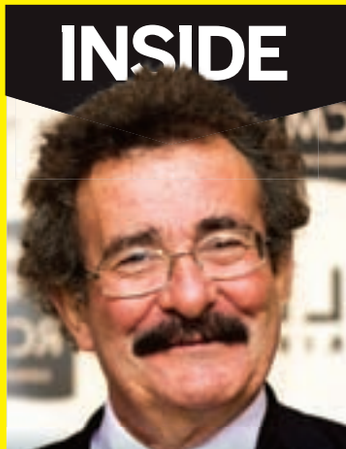
THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE



ROBERT WINSTON
Creating a new breed of future scientists

SUPER EARTHS
Revealed! The mysterious exoplanets beyond our solar system

BLUE WHALES
The largest creatures on Earth explained

THE STATUE OF LIBERTY
How and why the famous American landmark was built

MASSIVE MINING MACHINES
Inside the industrial behemoths that can level mountains

+ LEARN ABOUT
- FOUR-WHEEL DRIVE
- PARKING SENSORS
- SHOOTING STARS
- LIQUID NITROGEN
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- TRAFFIC LIGHTS
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HOW TO WEIGH A PLANET
Find out on page 56

LASER POWER

THE SCIENCE THAT DOES EVERYTHING FROM SLICING STEEL TO PLAYING MOVIES

MICRO MONSTERS
The tiny creatures that feast on your skin

LIFEBOATS
The incredible ships that save lives at sea

HUMAN BODY CLOCK
Why we feel tired at night and hungry at lunchtime

HOW EAGLES HUNT
Find out how these amazing animals catch prey

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IMAGINE PUBLISHING

HOW IT WORKS

WELCOME

The magazine that feeds minds! ISSUE ELEVEN

Get in touch

Have YOU got a question you want answered by the How It Works team? Get in touch by...

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"FEED YOUR MIND!"

Meet the experts

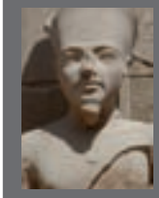
"Written by experts to be enjoyed by everyone" is how we like to roll, so meet the people that work so hard to bring you each issue...

Aneel Bhangu
Blood transfusions

You can trust Aneel, he's a doctor. Well, he's a surgeon to be more accurate and he's filled us in on how blood transfusions are performed on page 31.

Luis Villazon
Golden eagle

He's already prowled like a lion in issue 2 and our resident zoologist is back to soar like an eagle with his article on how the golden eagle hunts on page 23.



Dr Bridget McDermott
Enigma machine

Dr Bridget's varied expertise covers military history, so she snapped up the chance to write an article on the Enigma code machine used in the Second World War. See page 78.

Richard Aucock
Massive mining machines

We borrowed Richard from Total 911, one of our sister magazines. He seems to like it here so we assigned him the article on massive mining machines that begins on page 38.

Nigel Watson
Pluto

Nigel has a degree in psychology, and another in film and literature. He is interested in space exploration and is the author of books examining historical and psychological aspects of ufology.

With thanks to

How It Works would like to thank the following organisations for their help

sciencemuseum · DK · NASA · Mining Magazine · EMBRAER · LeTourneau Technologies · P&H · BUCYRUS · 2010

"All things bright and beautiful, all creatures great and small." It may seem strange to introduce a science magazine with a line from a hymn – and we're sure it would make Richard Dawkins frown – but it seemed like too wonderful an opportunity to pass up given that our subject matter this issue ranges from the amazingly micro to the massively macro, and even takes in a few things wise and wonderful along the way.

Issue 11 of How It Works looks at "the great" by way of articles on the largest animal on the planet, the blue whale, and the biggest machines on the planet, the behemoths of the mining industry. "The small" is covered by a look at some of the microscopic beasties living in our homes and even on our bodies, so get ready to start itching when you reach page 14. "Bright and beautiful?" Well, lasers cover the first and we've decided to celebrate the 50th anniversary of the laser with a look at how they work and all of their amazing uses – from death rays to Blu-rays. Golden eagles, shooting stars, Super Earths and even private jets all represent the beautiful, as does the How It Works team... well, some of them.

Among all this ecclesiastical referencing, it seems only right to add balance in the form of some words from Mr Eric Idle, who reminded us that "All things dull and ugly, all creatures short and squat. All things rude and nasty, the Lord God made the lot."

Be it bright or beautiful, dull or ugly, even short and squat, be sure to keep reading this magazine if you want to find out about all the amazing things in the world around us.

Dave Harfield
Editor in Chief

The sections explained

The huge amount of info in each issue of **How It Works** is organised into these sections

ENVIRONMENT
The natural world explained

HISTORY
Questions answered on how things worked in the past

TRANSPORT
Be it road, rail, air or sea you'll find out about it here

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

SCIENCE
Explaining the applications of science in the contemporary world

SPACE
From exploration to the solar system to deep space

Editor's pick

Environmentalists may well dismay but the massive mining machines article really pushed my buttons this month. It's hard not to be impressed by their breathtaking size and the amazing engineering that goes into these industrial behemoths.

What you're saying about How It Works

Written in a concise, straightforward style. I could give an issue to my 11-year-old nephew, and I feel quite certain that he would have no difficulty reading it.
Johnny Curuthers

I home educate our 11-year-old son and have been doing so for four years. We have been so impressed with the magazine that we have bought a copy each month as it covers a much wider variety of subjects than I do and he finds it very easy to understand and thoroughly enjoys reading it from cover to cover.
Fiona Todd-Dunning

My favourite interview was Simon Reeve. Next? I'd love to read an interview with James Wong from *Grow Your Own Drugs*. Or even Richard Hammond with his *Invisible Worlds*...
AndrewGear111

HOW IT WORKS

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The magazine that feeds minds!

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Take a visual and textual tour around the wonderful world of science, the environment and technology courtesy of our Global Eye section

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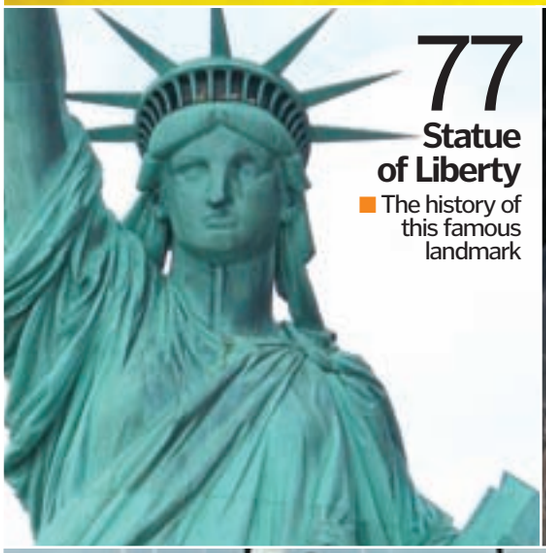
Celebrating the 50th birthday of the multi-talented laser



77 Statue of Liberty

The history of this famous landmark

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What are they and how are they formed?

70 Lifeboats

The RNLI shows us its new Tamar lifeboat

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BE NOW!

Dr Robert Bloomfield
Director IYB-UK

With a PhD in Genetics, Bob leads the panel of experts from the International Year of Biodiversity.

Dwain Clarke
Science Museum Explainer

New boy Dwain joins the long list of Explainers who've appeared in **HIW**.

Laura Brettle
Science Museum Explainer

Laura has a degree in astrophysics and has been an Explainer for four years.

There'll be some happy faces when the Dreamliner project is finally complete

A great sight, but will it all be worth the wait?

All images © Boeing

The green dream machine

Boeing's fuel-efficient Dreamliner makes its debut at Farnborough International Airshow

Despite its costly two-and-a-half-year delay, Boeing's 787 Dreamliner finally enjoyed a hero's welcome as it landed at Farnborough Airport at 9.09am on Sunday 18 July ahead of Hampshire's popular international aviation event.

Although its debut comes amid further rumour that the delivery date could fall back into 2011, Boeing maintains it has no plans to delay again. The introduction of new materials and new production processes has been a major factor in the postponement of the plane's launch.

Cutting fuel consumption by 20 per cent and slashing noise and CO_2 levels compared with similar planes, the Dreamliner is a unique craft. However, despite being constructed from advanced composite materials, which makes it lighter and faster than other similar-sized craft, the vehicle has come under yet more scrutiny as detractors suggest composites can't easily be monitored for wear and tear.

Nonetheless, since the aircraft's maiden flight between Washington and Seattle on 15 December 2009, Boeing has carried out rigorous flight-testing, right up to this debut voyage. "We took advantage of the flying time to conduct some flight testing on the way," said Boeing's Scott Fancher, vice president and general manager of the 787 programme.

The Dreamliner remained on display at the week-long event until the Tuesday when it ended the day's aerial display before returning home to Seattle where it was manufactured. The Dreamliner features large, dimmable window shades, increased overhead storage and cleaner air quality on board. The first airline to take delivery of the Dreamliner – hopefully before the end of 2010 – will be health-conscious launch customer All Nippon Airways in Japan.

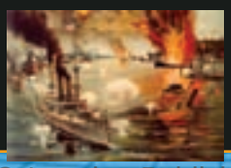
This day in history

12 August: How It Works issue 11 goes on sale, but what else happened on this day in history?

1762
The birth of King George IV at St James's Palace.

1851
The iconic Singer sewing machine is patented.

1898
The Spanish-American war over independence for Cuba ends peacefully.



1914
Britain declares war on Austria-Hungary during World War One.

1925
The identical twins Norris and Ross McWhirter, who co-founded the *Guinness Book Of Records*, were born on this day in 1925.

1946
We couldn't help it; it's ex-*The Really Wild Show*'s Terry Nutkins' birthday today. Happy birthday!

America to trial fake blood for soldiers

One of the main advantages of using 'pharmed' blood is that the material doesn't degrade

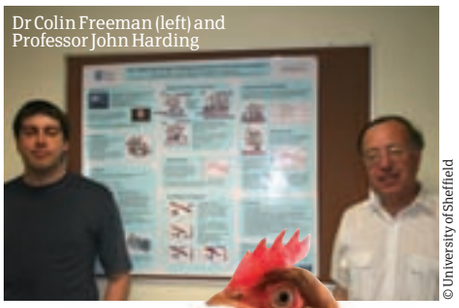
A technique called 'pharming' could save lives on the battlefield

American military technicians at DARPA (the Defense Advanced Research Projects Agency) have been funding the development of genetically engineered artificial blood for use in remote locations and battlefields.

The valuable substance could save the lives of service personnel in war zones by enabling the transfusion of blood in the field without the associated complexities of transportation and storage with donor blood. Manufactured by biotechnology firm Arteriocyte, the fake blood is produced using a technique called pharming, which can create vast quantities of medically useful red blood cells. The Blood Pharming programme involves the use of haematopoietic stem cells from old umbilical cords in the creation of 'universal donor' red blood cells in the same way that bone marrow produces new blood cells.

They've cracked it

British researchers uncover the answer to the age-old question: what came first, the chicken or the egg?


Dr Colin Freeman (left) and Professor John Harding

© University of Sheffield

Research carried out at the universities of Sheffield and Warwick has concluded that the presence of an egg-forming protein found in a chicken's ovaries means that the chicken must have come before the egg.

The findings offer conclusive proof that the formation of an egg is only possible if a particular protein called ovocledidin-17 (OC-17) is present in the chicken's ovaries. "It had long been suspected that the egg came first, but now we have the scientific proof which shows that in fact the chicken came first," said Sheffield University's Dr Colin Freeman.

Using the University of Edinburgh's High-End Computing Terascale Resources (or HECToR) supercomputer to zoom in extremely close, research has shown that OC-17 is a catalyst for the crystal growth necessary for shell development. This latest discovery could also prove important for the future development of advanced materials.

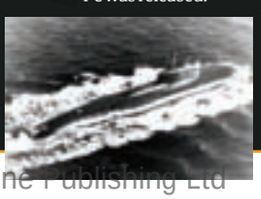
As Professor John Harding from Sheffield University's Department of Engineering Materials explains: "Understanding how chickens make eggshells is fascinating in itself but can also give clues towards designing new materials and processes. Nature has found innovative solutions that work for all kinds of problems in materials science and technology – we can learn a lot from them."


© NASA

1953 Measuring 7.3 on the Richter scale, the Great 1953 Ionian Earthquake shakes the islands of Kefalonia and Zakynthos.

1960 NASA's first communications satellite Echo 1 was launched. Measuring 100 feet across, it was nicknamed the 'Satelloon' by those working on the project.

1977 Although not capable of spaceflight, the Space Shuttle Enterprise was used to test flight control systems. She enjoyed her first free flight – meaning she flew on her own after the initial launch rockets had been disengaged.



1981 On this day in 1981, the original IBM PC was released.

2000 This date marks the tenth anniversary of the tragic sinking of the Russian Navy's Kursk nuclear submarine in the Barents Sea north of Norway, killing all 118 people on board.

MONTH IN FACTS

Short, concentrated bursts of facts and figures from the last month in news

Material world

■ Scientists at MIT have developed acoustic fibres that can detect and produce sound. So who fancies a singing jumper?

$200,000

■ The cost of a ride on the Virgin Galactic's VSS Enterprise. Its first crewed voyage took place over the Mojave Desert on 15 July.


© Mark Greenberg

15 kilo-metres per second

■ On 10 July, the ESA's Rosetta spacecraft flew past the mysterious Lutetia asteroid – the biggest ever visited by a spacecraft – at a speed of 15kmps.

Non-stop for four days

■ Boeing's recently unveiled unmanned, hydrogen-powered spy plane, the Phantom Eye, can stay at 65,000 feet for four days.

School of Dreams

■ ASIMO headed to Swindon in celebration of Honda's School of Dreams initiative, helping students to "understand the importance of pursuing their dreams".

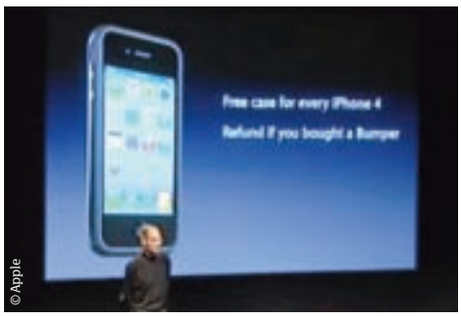

© Honda

Antennagate

Bumper give away costs Apple $180 million to fix the infamous signal problem

After the growing media coverage of the iPhone 4's alleged signal strength issue – whereby if users hold the device in a certain way they loose signal strength – and increasing amounts of complaints from consumers, Apple held a short-notice press conference on 16 July where it unveiled the company's plans to resolve the issue.

CEO of Apple Steve Jobs, in a lengthy presentation, then proceeded to unveil an updated iPhone OS and global iPhone 4 case giveaway to its customers. Speaking to the conference on what Apple had planned, Jobs said: "I'll tell you what we are going to do. The first thing we did yesterday was release IOS version 4.0.1, it fixes the wrong formula we used to calculate how many bars to put up for a given signal strength and their was a nasty exchange bug in there that a lot of our corporate customers were hitting and that is now fixed as well. So those bugs are fixed and IOS 4.0.1 is out and we recommend every iPhone owner update to it.



© Apple


© Matt Yohe
"Now you can hold it like this"

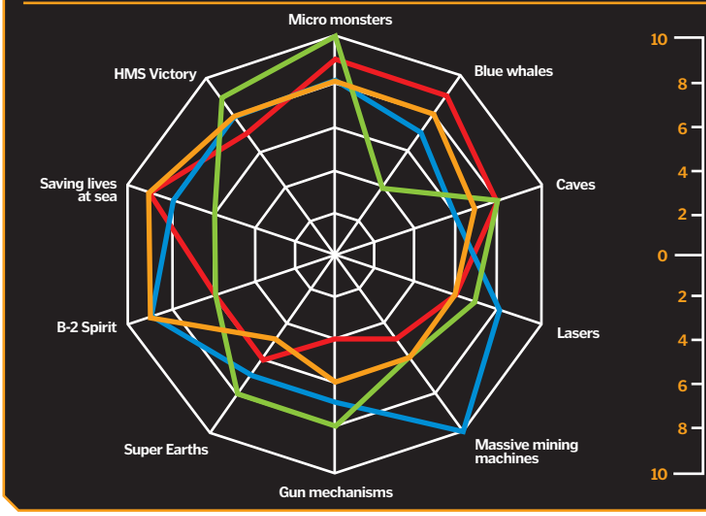
"Secondly, a lot of people have told us the bumper solves the signal strength problem," continued Jobs, "the consumer reports said it in the latest one this week: 'Why don't you just give everybody a case?' Okay, great. Let's give everybody a case. We want to give everybody a free case. One for every iPhone 4. If you have already bought one, we'll give you a full refund for the bumper, and we're going to do this for every iPhone 4 purchased through to 30 September."

Jobs continued to announce that users will have a choice of cases as Apple did not have the resources to produce the quantity required, which with 3 million current customers meant that third-party variants would instead be sourced. Analysts predict that the bumper giveaway could cost Apple as much as $180m (£118m).

© Apple
Breaking news... Apple isn't perfect!

THE EXCITE-O-METER!

What's on the radar of excitement? Take a look at this visual guide to what the team love most this issue...



Dave
Ed in Chief
I've already talked about the massive mining machines in my editorial and second on my radar of excitement is the B-2 Spirit bomber. Amazing technology and design that enables it to be almost undetectable by radar. It also cost a fantastic amount of cash!

Helen
Deputy Editor
I'm a fan of anything written by our resident zoologist Luis Villazon and so it was the article on the blue whale that really excited me this issue. These amazing mammals that live below the waves are just astonishing and Luis does a great job of filling us in on how they feed.

Rob
Staff Writer
It is all about micro monsters for me this month, and I have to admit it made me itch and scratch a little while researching and writing the article. They are fascinating organisms though, and tell us much about evolutionary priority at the smallest possible level.

Jon
Senior Sub Editor
Living just down the road from the RNLI headquarters made our four-page feature even more engrossing for me. It's easy to forget the great work these guys do day in day out, and if it wasn't for my queasy stomach I'd love a ride on the new Tamar!

AND THE VERDICT IS...

Helen's excitement drops this month due to low scores on gun mechanisms and massive mining machines. Dave's excitement remains super high though, with good scores across the board.

2 images © Bloodhound SSC

How fast could the Stig get that round the track?

Bloodhound SSC model unveiled

1,000mph rocket car transitions from fiction to reality

A model of the Bloodhound SSC has been unveiled at the Farnborough International Air Show, England. The model is a 1:1 replica of the 12.8 metre long supersonic car that has been in development for over three years and is the next stage in the project's goal to build and drive the first car capable of breaking the 1,000mph barrier.

At the show the team announced that aerospace manufacturer Hampson Industries will begin building the rear of the real vehicle in the first quarter of 2011. Speaking on the future transition from model to real thing, chief engineer Mark Chapman said that the team "now have a route to manufacture for the whole car and would hope to be able to shake down the vehicle on a runway in the UK at the end of 2011 or at the beginning of 2012."

The British-based team are the current world land speed record holders, a feat they accomplished in 1997 with their Thrust SuperSonic Car, reaching a staggering 763mph (1,228kph). However, the team believe that this car – with its superior aerodynamics and Falcon hybrid rocket and Eurofighter Typhoon jet engine – will far exceed that figure and go on to topple 1,000mph.

For more information about the Bloodhound SSC project and the current race to break the 1,000mph barrier, check out the 'Race to 1,000mph' feature back in issue 9 of **How It Works**.

Mercury rising

New images from the Messenger spacecraft show the planet Mercury like never before

The new images suggest the planet was home to magnetic substorms

2 images © NASA

NASA's Messenger spacecraft has returned images of the planet Mercury, indicating that the length the planet has been dead is not as long as previously believed by scientists.

Analysing the images and data closely, scientific teams at NASA believe that they indicate vividly Mercury's most recent volcanic activity, which does not complement the existing view that it has been long-dead and had a short (for a planet at least) life span. Contrarily, scientists now believe that the planet was active for much of its life span and by analysing its surface and composition further, it can help reveal how other planets in our solar system were formed and evolved.

Mercury is the closest planet to the Sun in our solar system and, since it was first imaged by NASA, has revealed its surface to be a scarred, crater-heavy wasteland, with only the remnants of long extinct volcanoes to be seen. However, the new data and imagery suggests that not only did those volcanoes rage for far longer than first thought, but also that there is strong evidence to suggest that Mercury was prone to intense and sporadic magnetic substorms – disturbances in a planet's magnetosphere causing energy to be released around its poles.

The Messenger spacecraft has enough fuel to orbit around Mercury until at least 2013 and – as noted by the Messenger's principal investigator Sean Solomon – "Once Messenger has been safely inserted into orbit around Mercury next March, we will be in for a terrific show."

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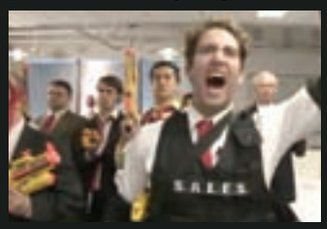
HOW IT WORKS TV

The How It Works site is regularly updated with the web's most amazing videos

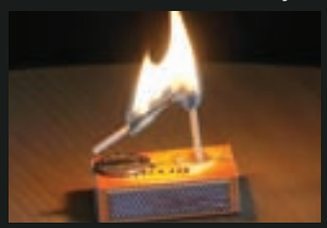
Nerf warfare

Watch as a standard office descends into all-out warfare thanks to one man and his clicky pen. Let the carnage begin!



Science party tricks

Professor Richard Wiseman from Hertfordshire University demonstrates a few simple, science-based tricks, that can be used to wow friends and family.

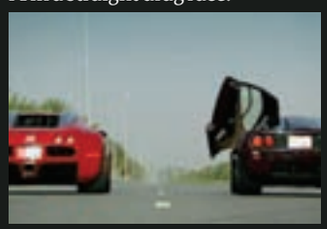


Oil cap

BP has finally capped the leaking oil well that has blighted the Gulf of Mexico. This video shows the momentous occasion.

Hypercar shootout

The *Top Gear* team do their usual thing here as they pit a Bugatti Veyron against a McLaren F1 in a straight drag race.



Professor Robert Winston

Straight-talking man of science Professor Robert Winston took time out to speak frankly to **How It Works** about the future of the *Child Of Our Time* series, his quest to create a new breed of literate young people, the damage being done by celebrity culture and his fears for the future of the sciences

How It Works: Your latest book for younger readers, *What Goes On In My Head?* explains how the brain works. How do you tackle communicating a subject like the brain to children without making it seem daunting.

Robert Winston: I don't see that it's any more daunting than any other part of science, frankly. Why would it be more daunting than, say, tackling evolution, which I've done in one of these books previously, or chemistry or the other subjects I've done? I don't think the brain is particularly difficult to tackle. It's a question of simply – as I always try to do with science both for adults and children – looking at the basic principles and talking about them.

HIW: What are your thoughts on modern science programming – both those shows designed to interest younger viewers (*Bang Goes The Theory*) and those aimed at more mature interests (*Wonders Of The Solar System*)?

RW: Not bad. Much of the stuff that is presented on television is somewhat dubious in how it explains stuff. A lot of it is quite formulaic and I'm disappointed there isn't slightly more imagination in the BBC to present science in a more dynamic way. I think Brian Cox – except for his recent series – really works very well. It will be interesting to see whether that can continue, but the BBC seems tempted to make him look like a pop star, which I think is a massive mistake. I don't think there's a need to do that. The BBC consistently tends to 'popularise' rather than actually explain. It's almost like it's lacking confidence in the way it does stuff.

HIW: How did you become involved with the ongoing *Child Of Our Time* series, which examines the lives of a group of children born in 2000 from different walks of life as they grow and change?

RW: I was involved from the very beginning when these women were still pregnant, and that was 11 years ago. In recent years, *Child Of Our Time* has not been allowed to explain the real science behind what is happening, and that's a pity. I think that *Child Of Our Time* could actually have more science content than it has, but I've always been in the hands of a production team and presumably a controller that doesn't want to see that happening.

HIW: From where did your interest for science originate? Who are your heroes?

RW: I think it's the wrong way to think about science. We talk about science heroes a lot [but] I don't think that's how most people get involved with science; I think people get involved with science because it's inherently interesting and because doing experimental and practical work is quite thrilling. I don't think that when I was a child I'd heard of Rutherford and so on. I mean, Darwin was certainly not an important figure in my childhood – actually he was completely irrelevant, as was Einstein. Of course they're heroes of science, but I don't think they're in the least bit inspirational and it surprises me that people seem to think they would be. I mean, why would Darwin or Einstein inspire an eight year old to think about science?

HIW: We were thinking about the work that they did and how it inspires people...

Professor Robert Winston FACTS

Robert Winston was born in London in 1940.

Winston earned a degree in medicine from the University of London. Then, throughout the Seventies, he continued his research into reproductive medicine around the world.

Professor Winston has long been involved with academia and remains Professor of Science and Society, and Emeritus Professor of Fertility Studies at Imperial College.

"I'm disappointed there isn't slightly more imagination in the BBC to present science in a more dynamic way"

Performing his duties as Professor of Science and Society at Imperial College London

RW: The work that they've done is not 'them'; the work is collaborative, collective. Evolution was a theory, which was not just Darwin's theory. It was a widely held and gradually worked-on theory. My own feeling is that actually talking about icons of science is a bit of a mistake – a bit like celebrity culture, which I don't think is a terribly thoughtful way of looking at our society. We always – and more now than ever – tend to go for celebrity. I think that's one of the problems with the way science is presented on television.

HIW: What is being achieved with your Reach Out Lab project that sees children going into universities to gain practical experience in the science lab?
RW: What we're achieving with the Reach Out Lab is extraordinary. Within a short space of time the Reach Out Lab is becoming over-subscribed. We are bringing in children from all over the place, who don't have good laboratories at school, who mostly don't have any aspirations to do science, who don't have any access to practical work. And we're presenting them with all-day practicals in all five sciences – physics, chemistry, biology, mathematics and engineering – starting from the age of six upwards. What we see is absolutely engrossed attention from children who don't normally show much interest in science. So during term time the place is full of children who I think are being turned on to the idea of being science literate.

But it goes beyond that: we're following up on those children to see what the impact is, and it's also affecting the teachers who come in with them and it's affecting the way they teach science. It's also having an effect on our under-gradate population and our post-graduate students at university who are suddenly thinking that teaching might be a profession that they should consider. [One] aspect of the Lab, which is very important, is to work out what kind of teaching works best. And in time we will have electronic teaching because we have web capability and we film everything we do and what I hope we will achieve in the future is that every university opens its doors in this kind of way to increase access between schools and universities. If we could wheel out this programme nationally it would cause a new breed of literate young people, literate in science as well as Shakespeare.

Inspirational teaching is very important. Hopefully, by offering these teachers a chance to sit back and relax in a university while other people are doing the teaching, we might encourage them to start thinking inspirationally about what they might do when they get back to their schools. One seven year old walked out of the lab saying, "I've learned more today than I have in my whole life." When children say that to you, you know that you've done something they will remember.

HIW: What is next on your to-do list?
RW: My next meeting. I work in the very short term and my next meeting is about synthetic biology, which will be this afternoon with the American politicians. We'll be looking at various aspects of creating organisms in the laboratory and what the ethical and other concerns about that will be.

HIW: You mention meeting with politicians, what are your thoughts on the subject of science and its education in Britain?
RW: It's extremely frightening. I'm very very concerned that this government may irreparably damage the British economy and British culture by not investing in all cultural aspects of what people do, including science. I think anybody who is thinking at the moment must be very worried indeed about the severe risk that they're taking by threatening to reduce so much public spending that we will not be able to do the research that in fact ensures our wellbeing and the future of our children.

HIW: Is there a gadget that you wouldn't be without – whether in your professional life or just a time-saving item you use at home?
RW: Yes, it's a trowel.

Robert Winston's incredible new book *What Goes On Inside My Head* is available now priced £10.99.

Learn more

For more information about the Reach Out Lab project supported by Professor Winston, visit www3.imperial.ac.uk/outreach/reachoutlab.

Professor Winston learnt to play the saxophone for the BBC show *Play It Again*

© Ian Gillett

Professor Winston is helping to get people interested in science again thanks to his Reach Out Lab project

All uncredited images courtesy of Robert Winston

He has written numerous books and presented a wealth of TV shows. His most popular productions include the BAFTA award-winning *The Human Body,* a bold series that took the viewer on an educational journey from birth to death.

Professor Winston is a member of the House of Lords and in parliament he often speaks on the subjects of science and education.

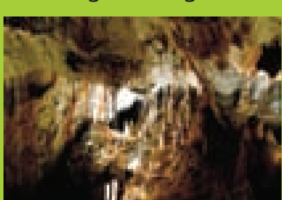
As well as his research at Imperial College London, Professor Winston is Chairman of the Royal College of Music and Chancellor of Sheffield Hallam University.

This month in Environment

This issue's environment section goes from micro to macro in the space of just a few pages, with micro being represented by the tiny beasties on this page and the next, and the macro corner being fought by the largest living creature on Earth, the blue whale. So once you've stopped itching from reading the micro monsters feature turn to page 20 to feel tiny and insignificant!

20 Blue whales

23 How golden eagles hunt



24 How caves form

ENVIRONMENT

A velvet mite, what a site!

Micro monsters

Largely invisible to all but the most powerful microscopes, a menagerie of micro monsters live all about us – in our homes, on our food and even on human beings themselves

5 TOP FACTS MICRO MONSTERS

Vampiric
1 A fully grown head louse bites the human scalp between three to five times each day in order to drink the blood, sucking it directly into their digestive tract.

Host
2 A louse's eggs, from which the next generation emerges, are actually attached to its host's hair directly, allowing for an instant transition post-hatch.

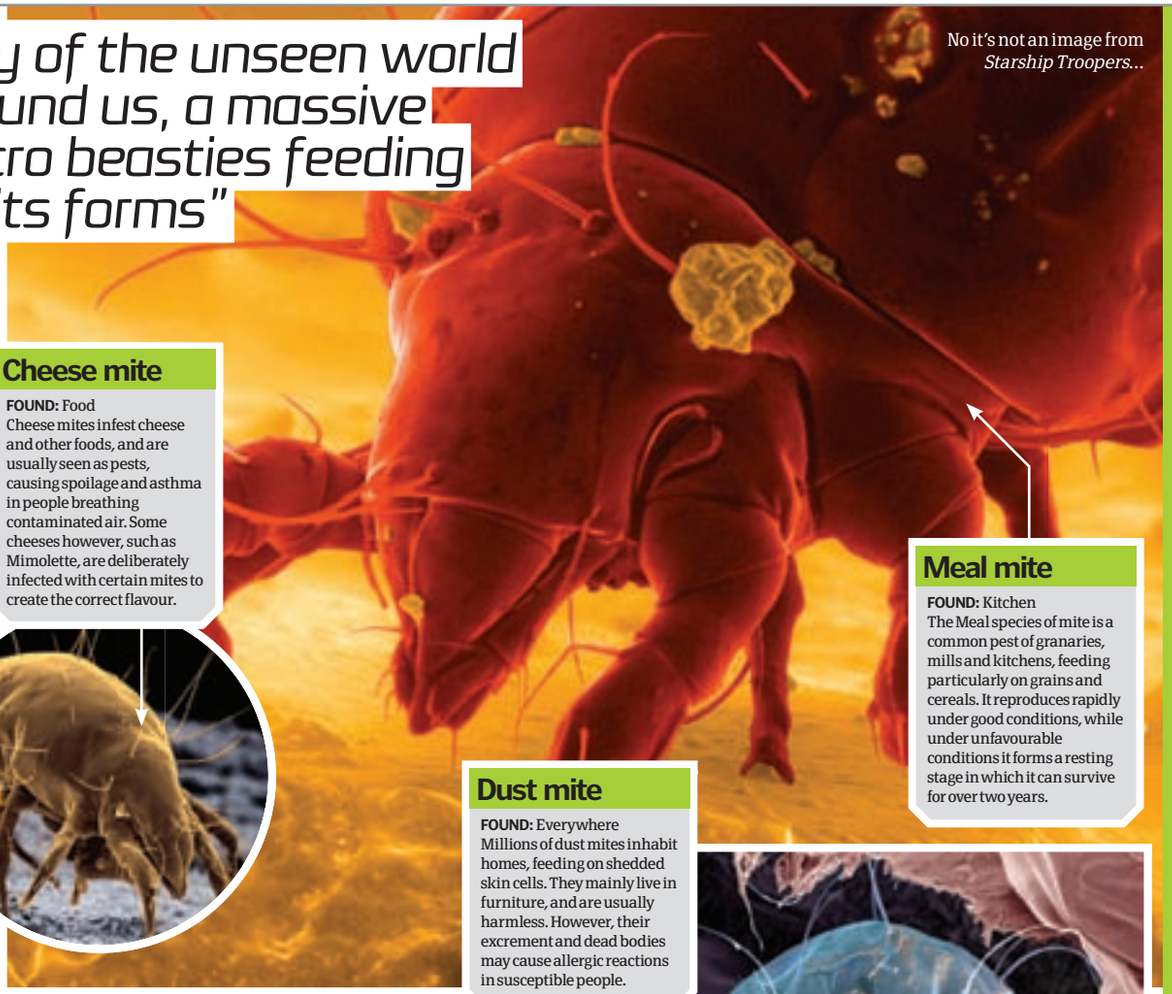
Bee-gone
3 One specific variant of mite, Varroa destructor, lives on bees alone. It is an external parasitic mite and spreads viruses that can kill entire colonies.

Sneezy
4 Mites are the cause of numerous allergies, including hay fever, eczema and asthma. They exacerbate these most in warm, humid conditions.

Mighty
5 The tropical variant of mite, Archegozetes longisetosus, is one of the strongest animals on Earth, capable of lifting 1,182 times its own weight.

DID YOU KNOW? *Scientists have identified over 48,000 species of mites, only five per cent of their estimated total*

"This is the reality of the unseen world operating all around us, a massive multitude of micro beasties feeding off carbon in all its forms"



No it's not an image from *Starship Troopers*...

Cheese mite

FOUND: Food
Cheese mites infest cheese and other foods, and are usually seen as pests, causing spoilage and asthma in people breathing contaminated air. Some cheeses however, such as Mimolette, are deliberately infected with certain mites to create the correct flavour.

Meal mite

FOUND: Kitchen
The Meal species of mite is a common pest of granaries, mills and kitchens, feeding particularly on grains and cereals. It reproduces rapidly under good conditions, while under unfavourable conditions it forms a resting stage in which it can survive for over two years.

Dust mite

FOUND: Everywhere
Millions of dust mites inhabit homes, feeding on shedded skin cells. They mainly live in furniture, and are usually harmless. However, their excrement and dead bodies may cause allergic reactions in susceptible people.

Mites

One of the oldest forms of micro monster inhabiting your house, the mite is among the most diverse and successful invertebrates on Earth

Mites, lice, silverfish and termites – but a small selection of the microscopic creatures living in your home and, if you refer to bath time as an annual event, on you as well. This is the reality of the unseen world operating all around us, a massive multitude of micro beasties feeding off carbon in all its forms, be that a human hair, a piece of cheese, inside your skirting board or on each other; it is a cut-throat world of silent, unseen organisms that have inhabited our planet for over the last 400 million years. Well, considering they have been alive so long, maybe it is we who inhabit their planet, as not only have they existed far longer than modern humans, but they are more numerous too, with their species numbering hundreds of thousands and their diversity unparalleled.

However, now with the usage of powerful scanning electron microscopes (SEM), scientists are prising open the doors to this unseen world and watching as beasts akin to the creations of the most fevered dreams take form in their millions, marching over a world that has long-since been their home, one in which they have adapted and evolved furiously and efficiently to exploit. Indeed, their appearance – grotesque by human standards – actually betrays their success as species: minimal, streamlined, sense-orientated and above all efficient, it is secondary to function, and gives us a valuable insight into the development and evolution of carbon-based life forms. After all, what use is it looking pretty if you cannot defend yourself from predators, scavenge food, and live in the most demanding of environments?

So strap yourself in as How It Works gives you a tour of some of the more common micro monsters living in your own home, as while they aren't for the squeamish, they are fascinating and intriguing life forms nonetheless which tell us much about organisms and evolution.

48,200 species have already been identified and scientists postulate that this figure is only five per cent of the total number of mites on Earth. They are strong (for their size), durable and – most importantly – highly adaptable to change, evolving quickly to exploit the different environments presented to them over millions of years. In fact they have proved so good at adapting to Earth's changing environment that mites – or more accurately, their sub-class Acari – have lived on Earth since the early Devonian period (416-359 million years ago), inhabiting the warmest and coldest climates and a vast array of living creatures. This evolutionary adaptability has granted mites almost unparalleled diversity and now, with the advent of the electron microscope, their numbers and types are visible for the first time.

Take the common house dust mite (Dermatophagoides pteronyssinus) from the pyroglyphidae family. This variant of mite dwells in human residences – including, as probability suggests, your home – and feeds entirely on organic detritus such as flakes of shedded human skin, flourishing in the stable environment and on the perpetual food supply. The dust mite is tiny and unseen, with a size of roughly 420 micrometers in length and 320 micrometers in height, highly reproductive – a female mite will lay 60 to 100 eggs in the last five weeks of her life – and impervious to all temperatures between 0°C and 60°C.

In essence, the dust mite is perfectly suited for life on Earth now, with the numbers of humans and houses in suitable climates (count yourself immune then in you live in Antarctica) in abundance. The ancestor that the common dust mite once shared evolved to take advantage of the rise of mammals (especially those which emerged from the nomadic tribal groups to set up permanent residences) and did so extraordinarily quickly. For while modern humans have only been around for 125,000 years, the Acari sub-class, as aforementioned, has been around for over 400 million. This efficiency and adaptability is common in many micro monsters, as we will see over the page.

Main image and 3 x mites pictures © Science Photo Library

"Head lice live on individual stands of human hair, clinging onto them with specially evolved crab-like limbs"

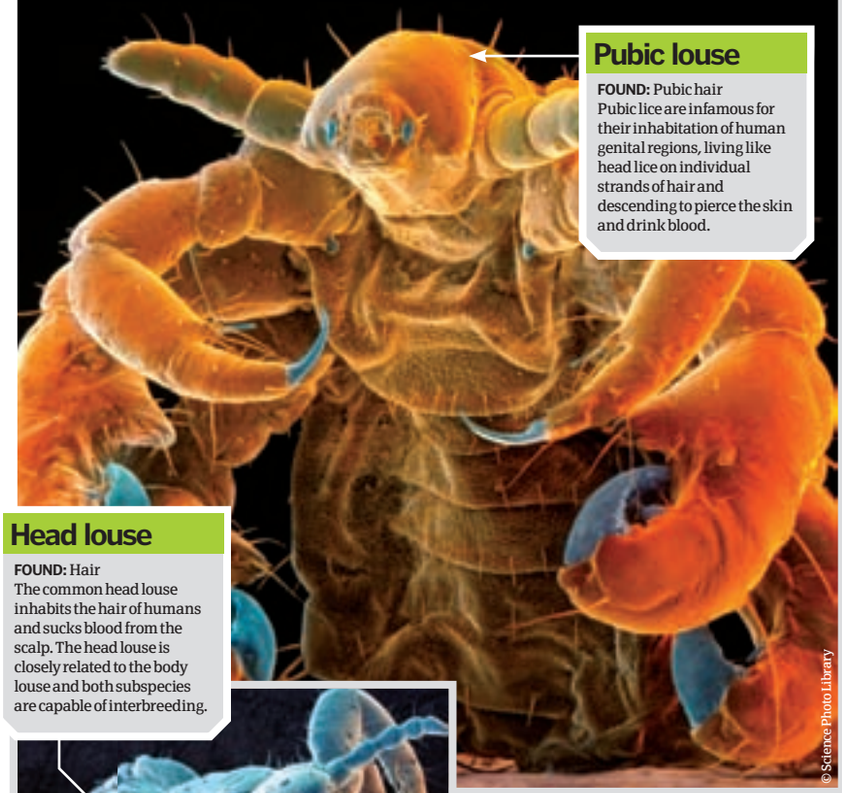

© SDaniel Schwen 07

SEM

The micro monster images contained within these pages come courtesy of scanning electron microscopes (SEM), which without we would not be able to observe. Electron microscopes produce electronically magnified images of specimens by utilising a particle beam of electrons. These electrons interact with the target's atoms and produce signals that contain information about the specimen's topography, composition and chemical properties. Vis-à-vis, the electron microscope – due to electrons having wavelengths roughly 100,000 times shorter than protons (visible light) – allows magnification of up to 1,000,000x, vastly greater than the most powerful optical telescopes, which are limited to 2,000x magnification.

Lice

Parasitic wingless insects, lice can be found on the majority of birds and mammals... including you


© Science Photo Library

Pubic louse

FOUND: Pubic hair
Pubic lice are infamous for their inhabitation of human genital regions, living like head lice on individual strands of hair and descending to pierce the skin and drink blood.

Head louse

FOUND: Hair
The common head louse inhabits the hair of humans and sucks blood from the scalp. The head louse is closely related to the body louse and both subspecies are capable of interbreeding.


© Science Photo Library

Louse eggs

A louse with its egg – it has been glued to a hair strand. The egg has a perforated lid, which is removed by the emerging nymph. A female louse lays between 80-100 eggs in a lifetime.

Lice are another species of micro monster that are close to home – literally – as not only are they found in your home but they live on humans themselves. In fact, lice cannot exist without a host (an obligate parasite), so it is rare to find them on non-organic matter. Most lice are scavengers by nature, feeding off the skin, blood and detritus found in and on the host's body, and often dwell in hair. There are over 3,000 species of louse (although only three are found on humans) and they live exclusively on avian and mammalian orders.

Head lice live on individual strands of human hair, clinging to them with crab-like limbs and measure two to three millimetres in length. To feed, the lice descend down to the scalp where they consume dead skin and drink blood – a process that involves the louse biting the scalp, injecting its saliva to clot the blood, and then extracting it into its body. When reproducing, female lice produce eggs that they attach to the strand of hair that they are clinging to with their sticky saliva. This means that when the egg hatches – young lice are called nymphs – they can move directly onto the same strand as their parent.

Scientists have discovered from analysing DNA evidence from modern humans' ancestors that lice spread to humans approximately 2,000 years ago from gorillas, who still share a susceptibility to lice.


2 x termite pics (second bottom right pp17) © Science Photo Library


© Science Photo Library

Silverfish

Nocturnal, razor-fast, silent: introducing the fastest micro monster your house has ever seen


You talkin' to me? You talkin' to me!
© Science Photo Library

Silverfish

FOUND: Bathroom / kitchen
Silverfish are minute and fast-moving insects covered in silvery scales. Adults range in length from 1.2-2.5 centimetres in length, with a tapering body, two long antennae and three bristles at the rear.

Another ancient species that has inhabited Earth for millions of years, the common household silverfish (Lepisma saccharina) is a tiny but visible insect in the Thysanura order. Often found in areas of high humidity – such as bathrooms – silverfish are elongated, flattened insects that measure between 1.2-2.5cm in length. They are not parasitic creatures, unlike mites and lice, consuming matter that is high in starches and sugars such as: cotton, paper, carpet, synthetic fabric and leather. Their speed comes courtesy of six legs and streamlined physical construction, allowing them to scuttle quickly and dynamically with minimal residence.

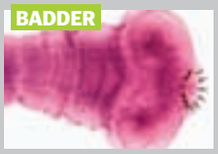
As with mites and lice, the silverfish is aesthetically unpleasant, but as with its fellow microscopic brethren it doesn't need to be and it is another good example of evolutionary priority. Despite the majority of its variants fitted with compound eyes, the silverfish technically doesn't require them – indeed, some varieties have none at all – as their finely tuned and large antennas and triple-arrayed cerci (largely rear-mounted appendages used as sensory organs) give it excellent positional awareness, and thanks to its monumental speed considering its size, it is an almost predatorless species, with only certain centipedes and spiders capable of hunting it. Finally, the silverfish can live for up to a year without eating, a fact that greatly enhances its ability to survive and, more importantly, reproduce.

BAD

1. Louse

Found on mammals and birds, the louse clings to its host via individual strands of hair, descending three to four times a day to drink its blood.

BADDER



2. Tapeworm

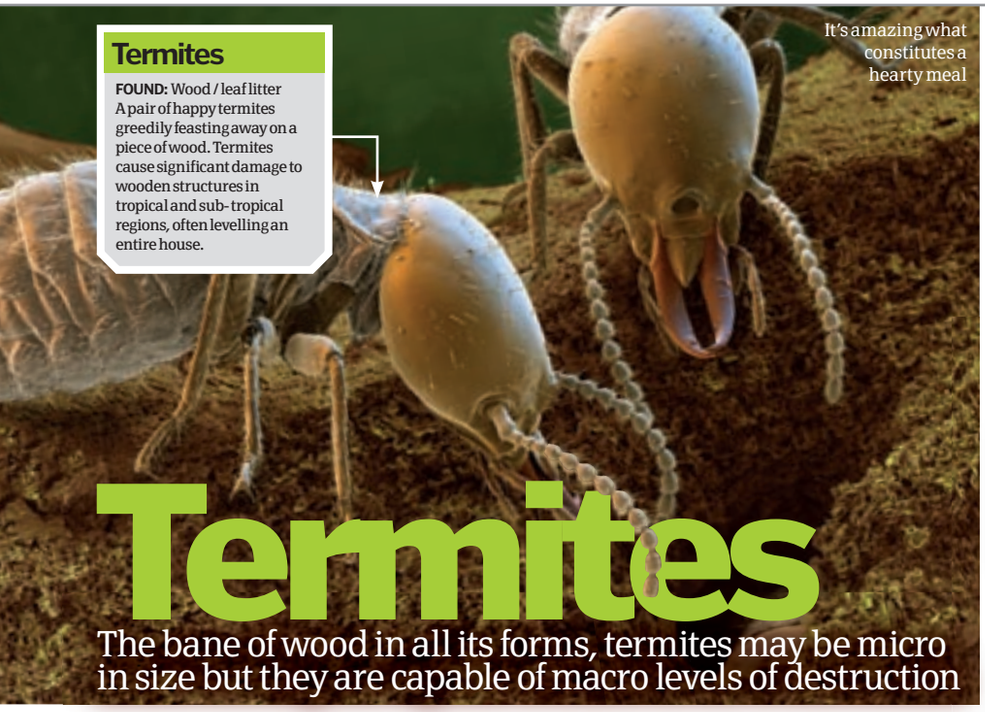
A worm that lives inside the digestive tract, the tapeworm absorbs nutrients through its skin from food consumed by its host as it is digested.

BADDEST

3. Mosquito

One of the most feared and prevalent parasites alive today, the mosquitoes suck the blood of their host and transmit various diseases including malaria.

DID YOU KNOW? *A species of ant, Globitermes sulphurous, protects its colony by exploding, trapping invaders in its sticky remains*



It's amazing what constitutes a hearty meal

Termites

FOUND: Wood / leaf litter
A pair of happy termites greedily feasting away on a piece of wood. Termites cause significant damage to wooden structures in tropical and sub-tropical regions, often levelling an entire house.

Termites

The bane of wood in all its forms, termites may be micro in size but they are capable of macro levels of destruction

Silverfish nymph

FOUND: Bathroom / kitchen
Young silverfish are referred to as nymphs and look like thinner, paler variants of the adults. They shed multiple skins on their way to adulthood where they adapt their silvery-blue coating.

While the other micro monsters featured here are potentially damaging to your health and belongings, the termite – a member of the Isoptera order – is neither a parasitic organism nor one that has a taste for your extensive How It Works magazine collection. Instead, they are major detritivores – organisms that feed by absorbing nutrients from detritus – that consume mainly dead plant material such as wood, leaf litter and soil. In nature this is a common behaviour and one that is invaluable to the ecosystem, contributing greatly to the effects of decomposition and recycling of nutrients. However, when it is the wooden beams of a human home, it becomes more of a problem.

Termites – albeit in a slightly devolved ancestral form – have existed on Earth from the early cretaceous period (145 million years ago) and are reasoned by scientists to be close relatives of cockroaches and mantids. They are eusocial and, arguably, more highly evolved organisms however, living in decentralised, self-organised colonies of hundreds to millions of individuals – split into job roles such as reproductives, workers and soldiers – each guided by a swarm intelligence that allows them to exploit a range of food sources and environments that a singular termite would not be able to do so. Further, their nests or mounds are toughened structures and provide protection against predators.

Home invasion...

Where in our homes do these invaders reside?

Carpets/curtains
- Velvet mites
- Dust mites

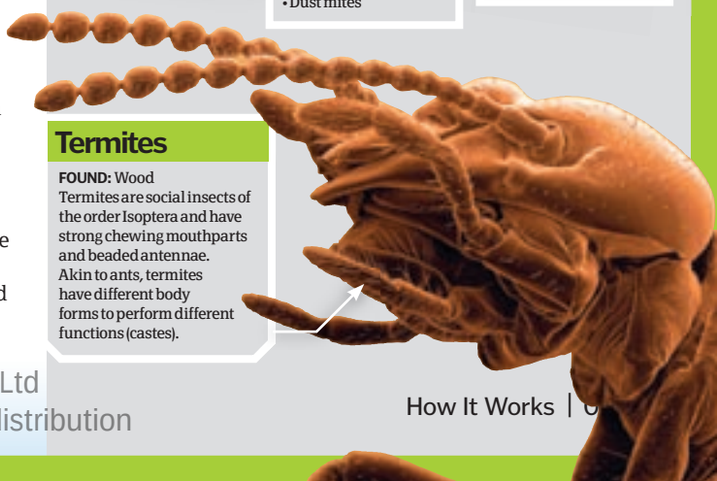
Living room
- Dust mites
- Termites

Kitchen
- Cheese mites
- Meal mites
- Silverfish
- Dust mites

Plants/pets
- Thread-footed mites
- Spider mites
- Gall mites

Bathroom/toilet
- Silverfish
- Silverfish nymphs
- Dust mites

Bedroom
- Bed bugs
- Dust mites



Termites

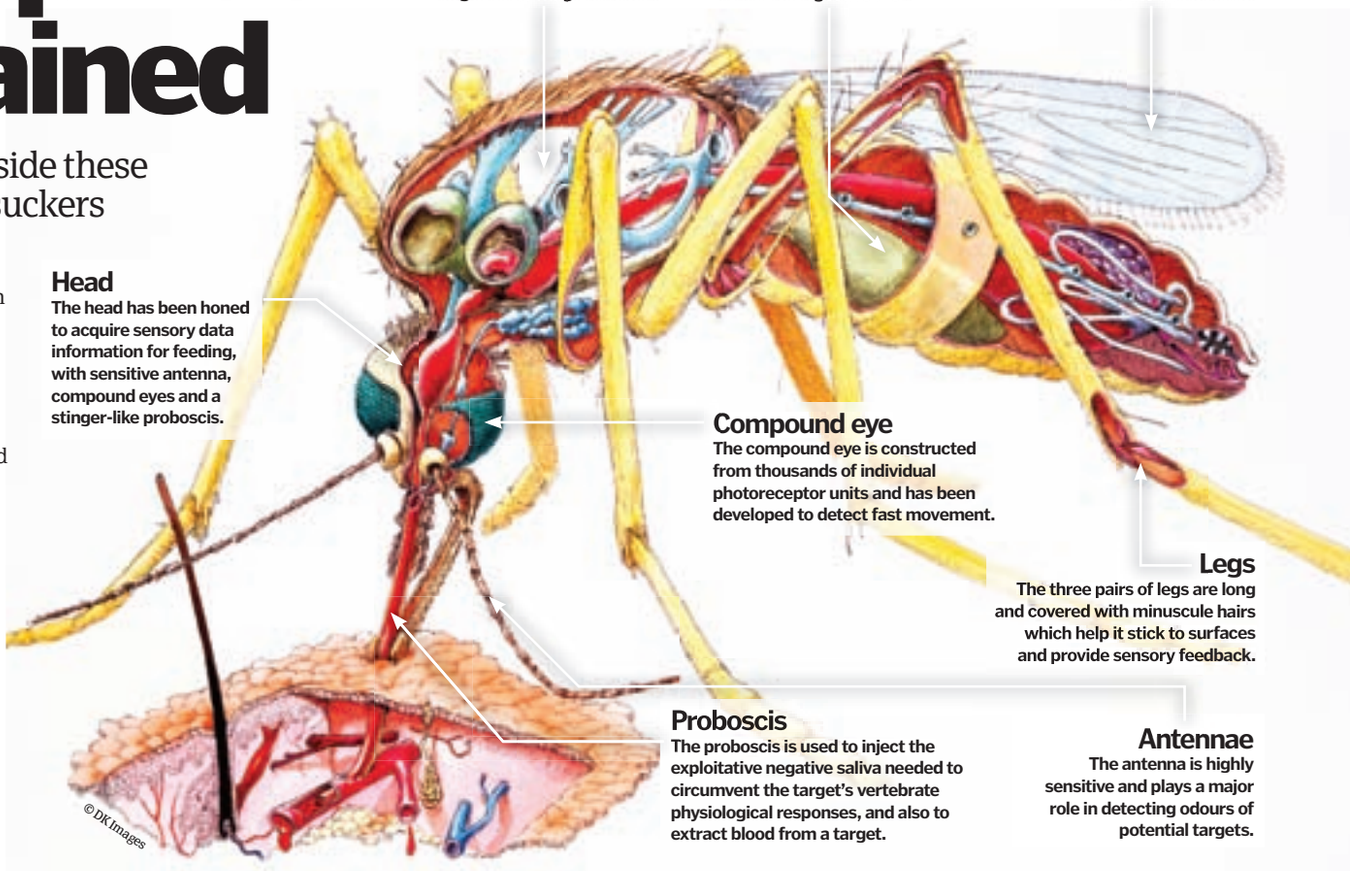
FOUND: Wood
Termites are social insects of the order Isoptera and have strong chewing mouthparts and beaded antennae. Akin to ants, termites have different body forms to perform different functions (castes).

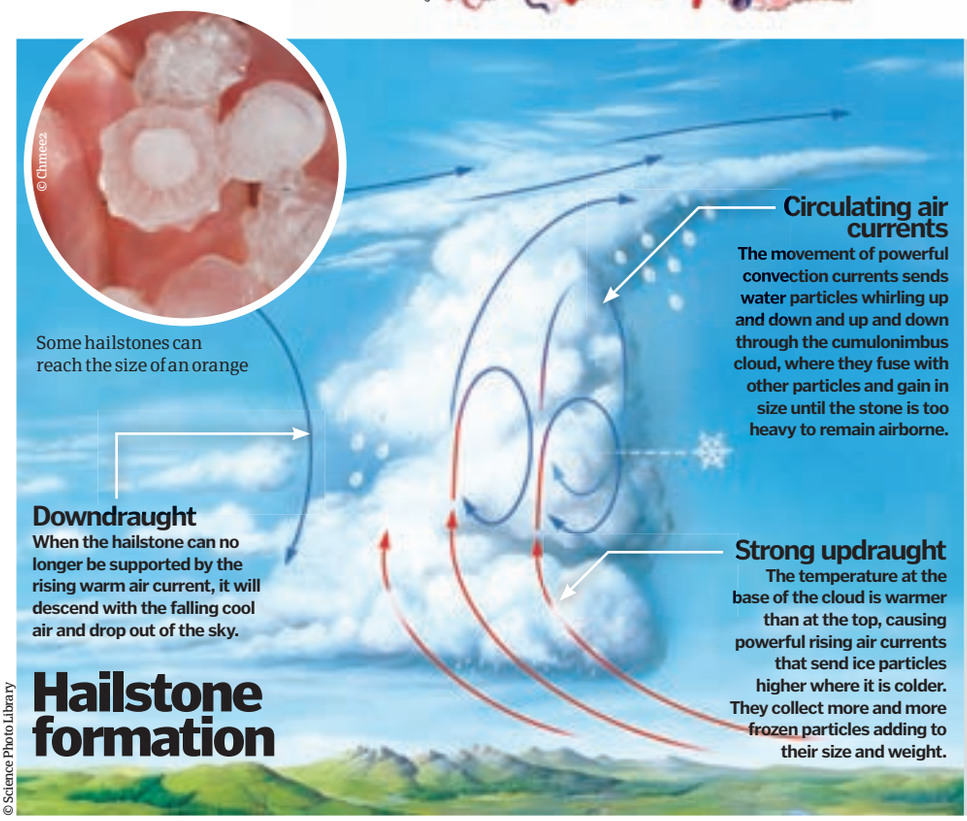
"Most hailstones are about the size of a marble"

Mosquitoes explained

We take a look inside these miniature bloodsuckers

Mosquitoes are nectar-drinking insects, which – in the case of the females – also drink blood (haematophagy). This is undertaken as the female needs to obtain nutrients there within – such as iron and protein – to help develop her eggs. Vis-à-vis, the common mosquito has developed a highly complex form and system in order to extract these substances from their target host, including a saliva that negatively affects vascular constriction, blood clotting, platelet aggregation and angiogenesis, allowing it to drink freely. We take a look at the mechanisms it has evolved in order to do so.





Hailstones

The balls of ice that fall to the ground, ruining crops, denting cars and smashing greenhouses

Hailstones form in the upper parts of freezing storm clouds – the cumulonimbus kind – which feature very powerful convection air currents that stretch up to ten kilometres into the atmosphere. They consist of many layers of either clear, hard ice, or softer milky snow, formed under different conditions, which can be seen if you slice a hailstone in half. Most hailstones are about the size of a marble, but can occasionally be as large as oranges.

Water droplets form inside storm clouds and are drawn upwards by strong rising air currents where they turn into ice. On its journey up, an ice particle will bump into even colder water particles – they then stick together and gain in size and weight, creating another layer of ice. As the hailstone grows heavier, it falls back down through the cloud, colliding with yet more ice particles on their way up.

The hailstone can circulate around the cloud many times, gaining more and more layers of ice, until it becomes too heavy for the air current to support. At this point it will drop out of the cloud completely, falling to earth.

"The calf drinks more than 400 litres of milk a day"

Blue whales

What's as long as three London buses and as heavy as 112 giraffes?

The blue whale isn't just the largest animal alive, it is the largest animal ever to have lived. Even the largest dinosaurs are topped by this leviathan. Everything about the blue whale is huge. It has a heart the size of a small car, a tongue that weighs 2.7 tons and lungs that can hold 5,000 litres of air.

Blue whales spend most of their lives swimming alone or in pairs, unlike other baleen whales such as the humpback. The female gives birth every two or three years to a single calf that weighs as much as an adult hippopotamus. For the first seven months, the calf drinks more than 400 litres of milk a day to enable it to put on 90kg of weight every 24 hours.

Blue whales aren't really very blue. The top half of their body is a bluish grey and the underside is a lighter colour to make them harder to see when viewed from below, against the sky.

Blue whales are also extremely fast swimmers. They cruise at 20kph and can sprint at 50kph. This makes it virtually impossible for barnacles and other parasites to attach themselves. In spring, however, a thin film of diatom algae growing on the skin can sometimes give them a yellow-orange hue and 19th Century whalers referred to them as 'sulphur bottoms'.

Despite their size, blue whales are preyed upon by orcas (killer whales) and 25 per cent of adult blue whales show orca bite scars.

One in four blue whales show scars caused by orcas

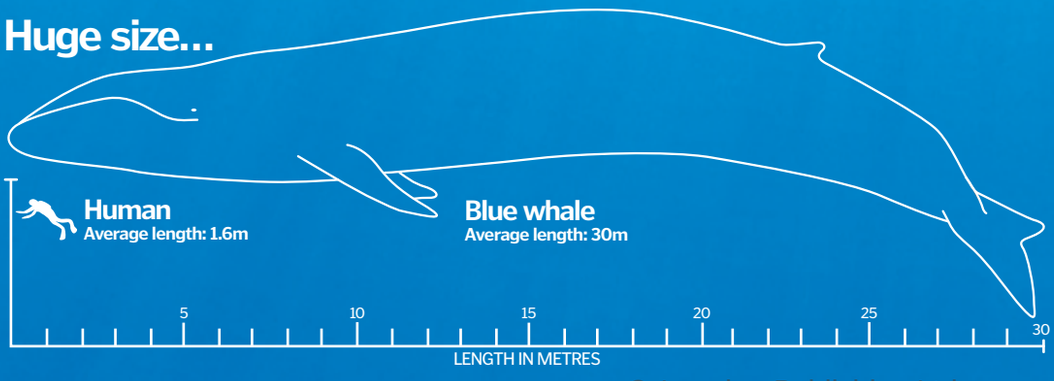
Baleen plates
The blue whale doesn't have teeth. Instead the baleen plates hang down to create a colander made of keratin.

Rostrum bulge
This oil and wax-filled chamber focuses sonar pulses, used for echolocation.

Ventral pleats
60 to 90 folded grooves expand the mouth to six times its size after a huge gulp of water and krill.

Pectoral fin
Three metres long and used like the diving planes in a submarine to adjust depth and for steering.

Huge size...



A blue whale swimming with her calf

5 TOP FACTS LARGEST MAMMALS

African elephant
1 SIZE: 5,400kg
The largest land animal currently living. Elephants are large enough to be safe from all predators but must spend 16 hours a day eating.

Polar bear
2 SIZE: 600kg
The largest bear and the largest land carnivore, although it spends much of its time in the sea. Its bite can crush a seal skull.

Mountain gorilla
3 SIZE: 200kg
The largest primate. Although they have powerful canine teeth, they are herbivores with a diet that includes celery, bamboo and stinging nettles.

Whale shark
4 SIZE: 36,000kg
The largest fish, whale sharks are filter feeders like the blue whale, but their food is even smaller than krill – microscopic plankton.

Blue whale
5 SIZE: 180,000kg
The largest animal that has ever lived. Its upper lip bone is the largest bone in the animal kingdom ever discovered.

DID YOU KNOW? *A blue whale's heart beats five times a minute. It pushes ten tons of blood through a million miles of vessels*

ON THE MAP

Where to find blue whales

Shown in blue, these behemoths roam virtually the whole ocean, following the seasonal abundance of the various species of krill. They avoid shallow seas such as the North Sea however, because their main defence against orca attacks is their ability to dive deeper.

Tail flukes
Like all whales, the tail flukes are horizontal, unlike a fish's vertical tail. Capable of propelling the whale at 50kph.

Blue whale anatomy

The body of a giant

Dorsal fin
Tiny, compared to sharks and many other whales. In some blue whales, it is barely more than a slight bulge.

Blow holes
Blue whales have twin blow holes, like nostrils. They are protected by a splash guard to the front.

Blubber
Up to half a metre thick in places. It conserves body heat and keeps a rigid shape to reduce drag.

The Statistics

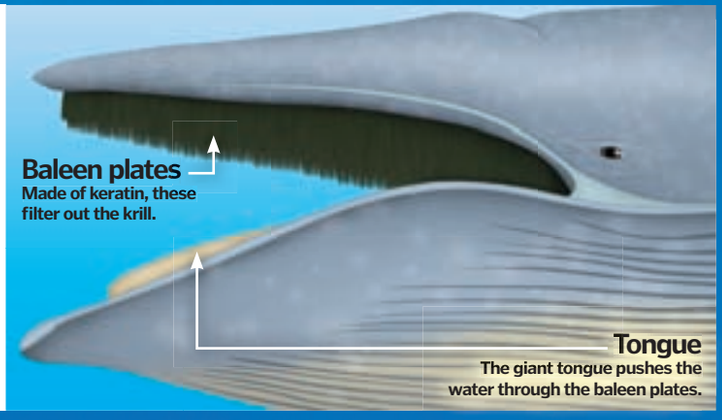
Blue whale

Type: Mammal
Diet: Carnivore
Average life span: 80 years
Weight: 180 tons
Size: 30m

How does the largest animal feed on one of the smallest?

Blue whales don't eat plankton. Instead they eat krill, which are one step up from plankton in the food chain. Krill resemble small shrimp, except that they swim in open water in huge swarms. Most krill are only a couple of centimetres long and since a blue whale needs around 1.5 million calories every day, that means it needs to eat a lot of krill – up to 40 million a day, in fact.

To catch them, a blue whale swims at speed towards a swarm and opens its mouth to gulp in 90 tons of water at a time. It then uses its massive tongue to force the water back through the baleen plates. These are 300 feathery bars, each one a metre long, that are attached to the upper jaw. They are made of keratin, like your fingernails. The krill get sieved out by the baleen and then swallowed.



Baleen plates
Made of keratin, these filter out the krill.

Tongue
The giant tongue pushes the water through the baleen plates.

Carrying umbrellas on motorbikes can damage your health

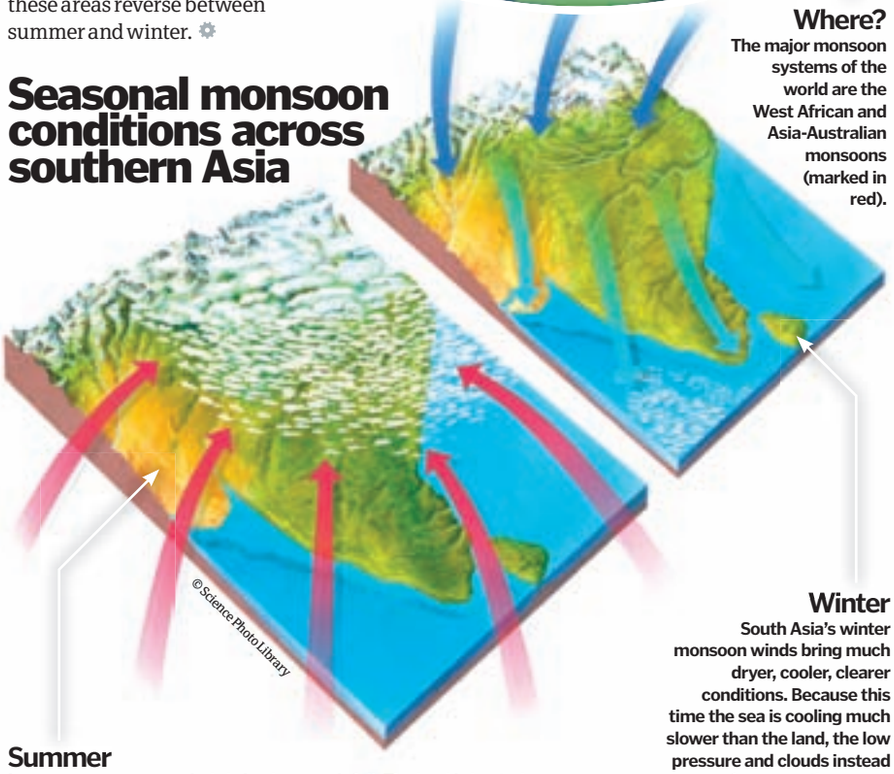
Monsoons

The wind systems that reverse seasonally, bringing dramatically different weather to subtropical regions

Monsoons are seasonal wind systems occurring in tropical and subtropical regions south, southeast and east of the large landmasses in the northern hemisphere. They see the prevailing wind direction and conditions in these areas reverse between summer and winter.

Where?
The major monsoon systems of the world are the West African and Asia-Australian monsoons (marked in red).

Seasonal monsoon conditions across southern Asia



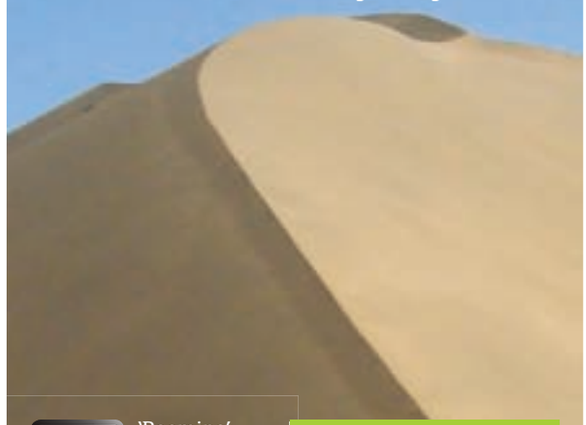
© Science Photo Library

Summer
In summer, monsoon winds bring heavy rainfall. The land is heated much quicker than the ocean, causing the warmer air to rise, creating a strong, large area of low pressure. The cool, wet air from the ocean is drawn in, bringing with it warm southwesterly winds. When the moist air reaches the Himalayas, clouds form and produce heavy rainfall that can lead to flooding.

Winter
South Asia's winter monsoon winds bring much dryer, cooler, clearer conditions. Because this time the sea is cooling much slower than the land, the low pressure and clouds instead form over the ocean, drawing the cool, dry air from the mountains into the area. These winter monsoon winds blow from a northeasterly direction.

Why do sand dunes sing?

Some sand dunes make sounds like didgeridoos, but the reason why remains a scientific mystery



'Booming' dunes have invoked fear and curiosity for centuries, but scientists remain uncertain how they work. One reason is they're rare – found in around 30, usually isolated, places worldwide.

Booming dunes can sound like musical instruments because they produce a single, droning note – E, F or G – for up to 15 minutes. It's thought dunes boom if loose, smooth, similar-sized sand grains avalanche down over a harder, wetter underlying layer. The dune must be at least 45m high and at an angle of around 35 degrees to avalanche.

The layers act like a violin – the dry particles vibrate like the strings, while the harder layer magnifies the sound like the instrument's hollow body. The grain size and depth of the loose sand controls the 'note' that the dune 'plays'.

'Squeaking' sands are found on many beaches. The whistling lasts under a second and is caused by friction when sand grains rub together.

Head to Head
NATURALLY OCCURRING NOISES

LOUDEST EVER

1. Volcanic eruption
The 1883 eruption of Krakatoa, Indonesia, may be the loudest sound ever recorded. It was heard in Australia and Bangkok.

VERY LOUD

2. Blue whales
Blue whales are among the noisiest animals alive with songs reaching more than 165 decibels.

SMALL BUT LOUD

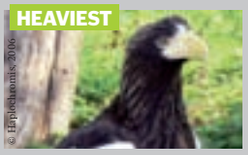
© OpenCage

3. Pistol shrimps
Their snapping claws can generate over 200 decibels of sound to stun their prey.

Head to Head EAGLES

1. Martial eagle

The title for the largest eagle is hotly contested, but the martial eagle of Namibia has a wingspan that can reach 2.6m.



2. Steller's sea eagle

This fish-eating eagle lives on the Kamchatka Peninsula in northeast Asia and can weigh up to nine kilograms.

3. Philippine eagle

With a body length of up to 112cm, the Philippine eagle isn't just the longest, it also has the longest life expectancy. Some are estimated to live for as long as 60 years.

DID YOU KNOW? *Golden eagles have learnt to kill tortoises by scooping them up and dropping them to crack open their shell*

How golden eagles hunt

Telescopic vision and terrifying talons: be glad you're not a Scottish rabbit

Golden eagles are apex predators, adapted to hunt in very harsh landscapes. With a wingspan of more than two metres, they are huge birds, capable of lifting prey weighing as much as five kilograms. There are documented cases of golden eagles attacking adult deer and even a bear cub but their usual targets are hares, foxes, grouse and, on the coast, seabirds.

Golden eagles nest in trees and on remote mountain crags. They can't hunt in thick forest so they have specialised to scour moors and uplands. Food is much scarcer here and the eagles have to patrol huge territories; sometimes as much as 160km². To do this they operate like stealth bombers, flying very high above the ground to scan a wide area without alerting their prey. They need to be able to soar for hours at a time and strong enough to kill whatever animal presents an opportunity.

Anatomy of a hunter

Flexible neck
Because the eyes are so large, they can barely move in their sockets. Instead the neck twists 270 degrees.

Large eyes
Facing forward to provide excellent binocular vision. They can spot a mountain hare from two miles away.

Primary feathers
The gaps between the 'fingers' of the primary feathers help to fine-tune the airflow over the wings.

Powerful wing muscles
Golden eagles can weigh up to 7kg but must be able to take off from the ground in a single bound.

Feathered legs
Unlike the long, bony legs of a swan, these are short and well muscled, with feathers to keep them warm.

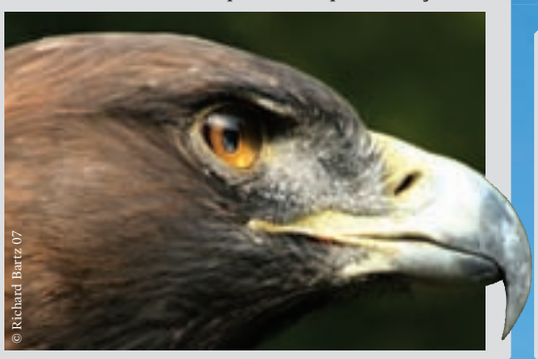
Tail
The tail can act as a rudder, to compensate for crosswinds or be spread wide to increase lift.

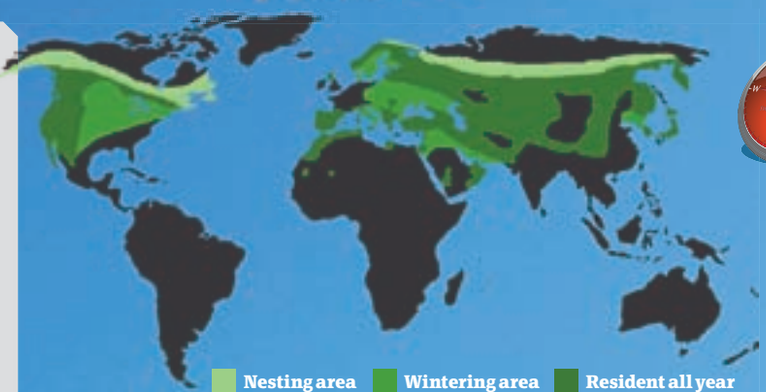
Deadly talons
The curved claws restrain prey and kill it. Smaller animals are simply carried aloft, back to the nest.

Eagle-eyed hunters

Eagle eyes are very large, relative to their body size: if our eyes were similarly proportioned, they would be the size of oranges. They also have 600,000 cone receptors per mm² on their retinas – four times the density in human eyes. These factors combine to give golden eagles two and a half times better resolving power in their vision.

Golden eagles have a translucent second eyelid, called a nictitating membrane, which blinks sideways. In the last moment before the eagle strikes, this membrane closes to protect the precious eyes.


© Richard Bartz 07



ON THE MAP

Golden eagles need wide open spaces with access to cliffs or trees for nesting but without dense woodland. In more northerly latitudes, this terrain can extend all the way down to sea level. Further south, golden eagles stick to the mountains.

Death from the sky

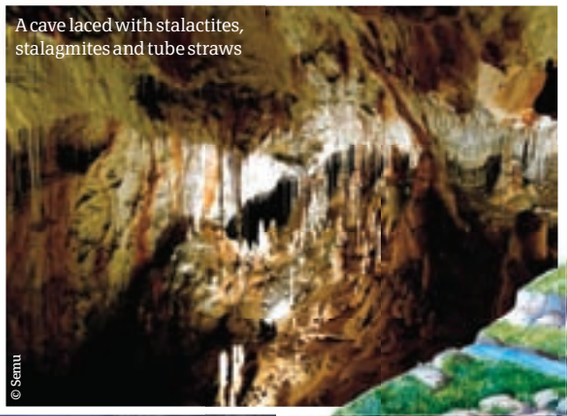
The golden eagle rarely attacks prey directly from altitude with a dive bomb or 'stoop'. Instead, it wheels out of the sky, some distance away and swoops in from downwind, close to the ground. The eagle relies on a sudden overwhelming attack. If it misjudges the initial strike, it's unlikely to prevail in a chase.

Golden eagles use the primary feathers on their wingtips to control the turbulent vortices of air along the trailing edge of the wings and increase lift. The eagle can spread its tail wide to merge with the wings into a single 'delta wing', or folded for maximum speed.

"Seemingly endless gutters running down and down into the Earth"


A cave explorer lowers himself over 600 feet into a sinkhole

© Dave Bunnell


A cave laced with stalactites, stalagmites and tube straws

© Semu

Soluble rock
This, a good cross-section diagram of a formation of solutional-formed caves, demonstrates how soft soluble rock is eroded over time by acidic groundwater. Water becomes acidic through a combination of climate effects (pollution) and by being absorbed by/passed over organic hydrocarbons.

© Hugo Soria

Caves

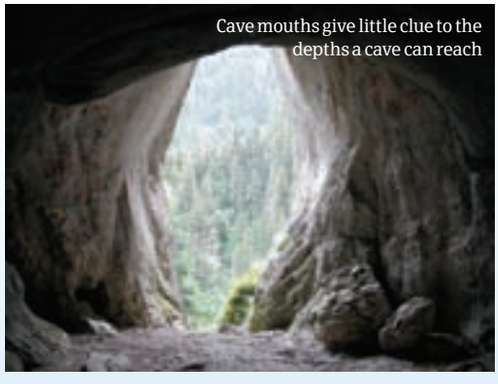
Formed over millions of years, caves are wondrous and diverse natural phenomena, which have held humans in both awe and dread for thousands of years

Solutional caves, as found across the Yucatan peninsula, are the most commonly occurring Earth cavities found across the globe. They are formed when a soluble rock such as limestone or marble is dissolved slowly by natural acid in the resident groundwater that seeps through the planes, faults and joints which, over epochs, slowly become cracks, then gulleys and finally caves. This dissolving process produces a distinctive landform known as 'karst', which is characterised by subterranean drainage, sinkholes and extensive interlinked cave networks.

The other most notable feature of solutional caves are the striking calcium carbonate formations that are produced by the slow precipitation of acid-laced groundwater. These formations include: stalactites – from the Greek "that which drips", a type of secondary mineral that hangs from the ceiling of caves; stalagmites – from the Greek "drop", a secondary mineral material which drops from the ceiling to the floor where it forms a calcium carbonate deposit; and soda straws, which are thin mineral tubes that grow out of cracks and carry water in their interior.

While solutional caves are by far the most common caves found world wide, other varieties also exist and can be formed in numerous different ways. Primary caves for example are formed at the same time as the surrounding rock, instead of afterwards like the solutional varieties that we've mentioned before. These caves are mostly formed by lava flowing downward and cooling and solidifying on top, while continuing to progress at the base, creating a lava tube once dissipated.

Another variety of cave formed in a similar manner to primary caves are glacial caves. Here, caves and tunnels are formed when embedded ice melts under glaciers and – as with the lava – flow downwards before eventually freezing again on top and solidifying once more. Finally, littoral caves (commonly referred to as sea caves) are formed when coastal rock is eroded away by the tidal action of the ocean waves, eating away at soluble rock along weakened points such as fault lines.


Cave mouths give little clue to the depths a cave can reach

5 TOP FACTS CAVES

Down
1 The deepest cave in the world is the Krubera (Voronya) Cave in Abkhazia, Georgia, at over 7,188 feet in depth. That is the equivalent of a vertical drop of 1.4 miles (2.3km).

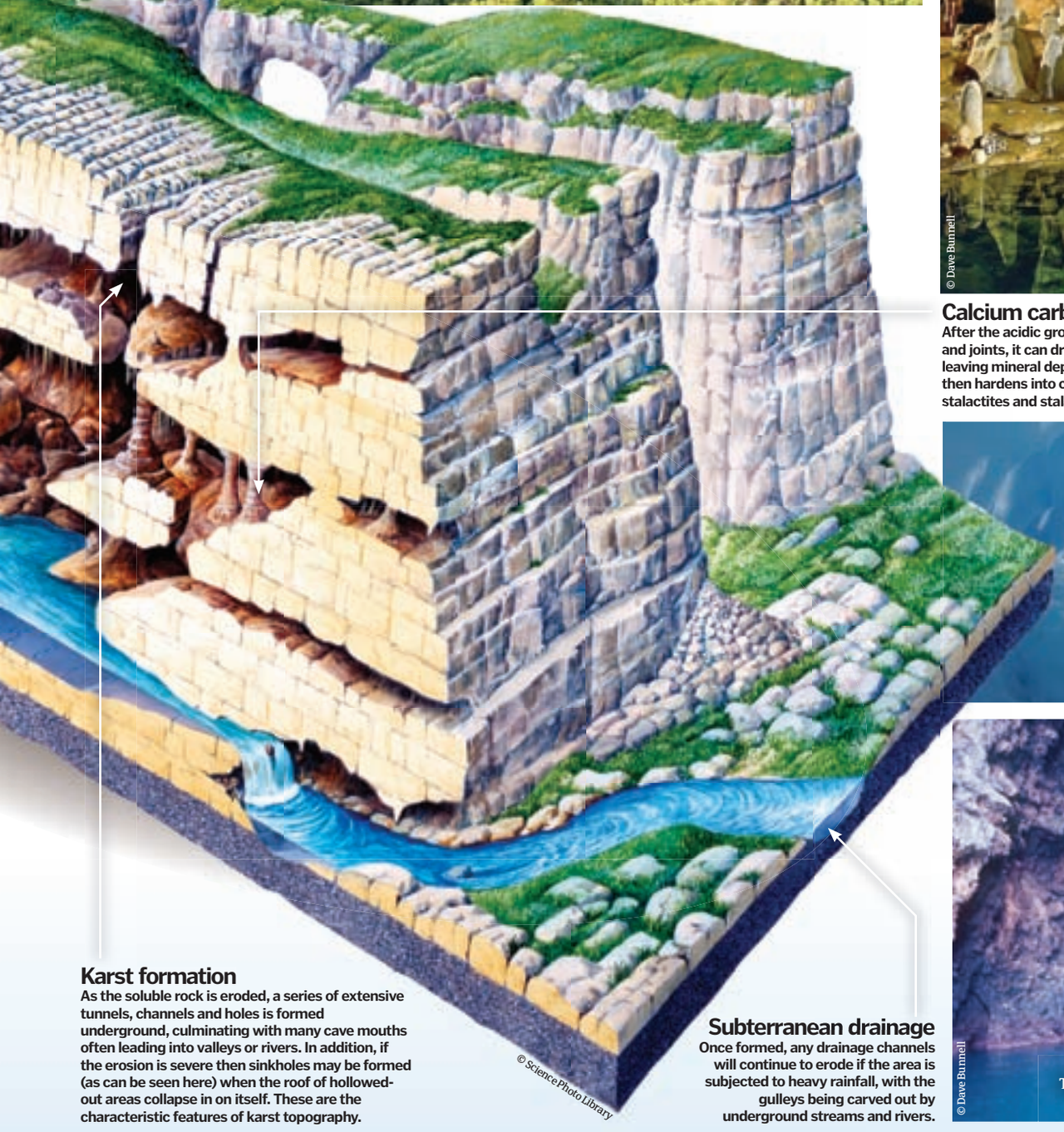
Eye
2 Polyphemus, the son of Poseidon and Thoosa, is said in Homer's Odyssey to trap Odysseus and his men in a large cave. Odysseus escapes by blinding Polyphemus.

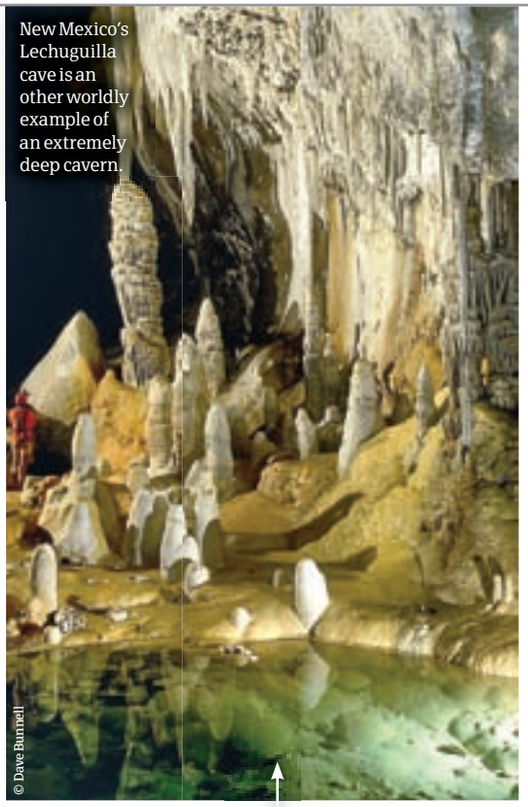
Troglo
3 Cave-dwelling animals fit into three categories: troglobites (cave-limited), troglophiles (live in and out of caves), and trogloxenes (need caves to complete their life cycle).

Lair
4 The only superhero to have their base of operations in a cave is Batman, who utilises an extensive cave network underneath and adjacent to Wayne Manor.

Potty
5 The traditional British term that is used to describe recreational cave exploration is 'potholing', while the American term to describe said activity is 'spelunking'.

DID YOU KNOW? *The longest cave system in the world is the Mammoth Cave System in Kentucky, USA*



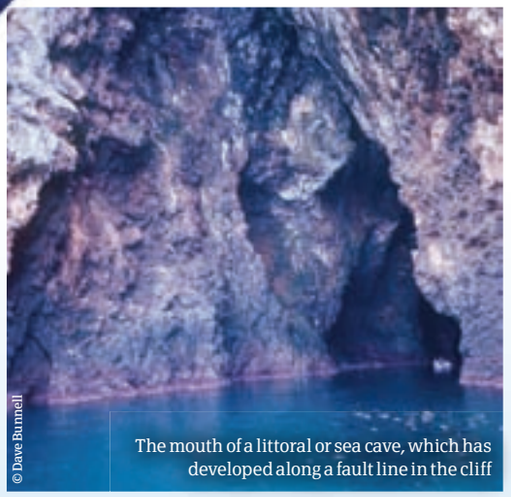


New Mexico's Lechuguilla cave is an other worldly example of an extremely deep cavern.

© Dave Bunnell

Calcium carbonate
After the acidic groundwater penetrates the rock's planes, faults and joints, it can drip down from the ceiling of a preformed cave leaving mineral deposits either at its base, or on its roof, which then hardens into calcium carbonate formations such as stalactites and stalagmites.

Ice caves form when melted ice flows downwards before resolidifying, leaving long tube-like formations underground



© Dave Bunnell

The mouth of a littoral or sea cave, which has developed along a fault line in the cliff

Karst formation
As the soluble rock is eroded, a series of extensive tunnels, channels and holes is formed underground, culminating with many cave mouths often leading into valleys or rivers. In addition, if the erosion is severe then sinkholes may be formed (as can be seen here) when the roof of hollowed-out areas collapse in on itself. These are the characteristic features of karst topography.

© Science Photo Library

Subterranean drainage
Once formed, any drainage channels will continue to erode if the area is subjected to heavy rainfall, with the gulleys being carved out by underground streams and rivers.

This month in **Science**

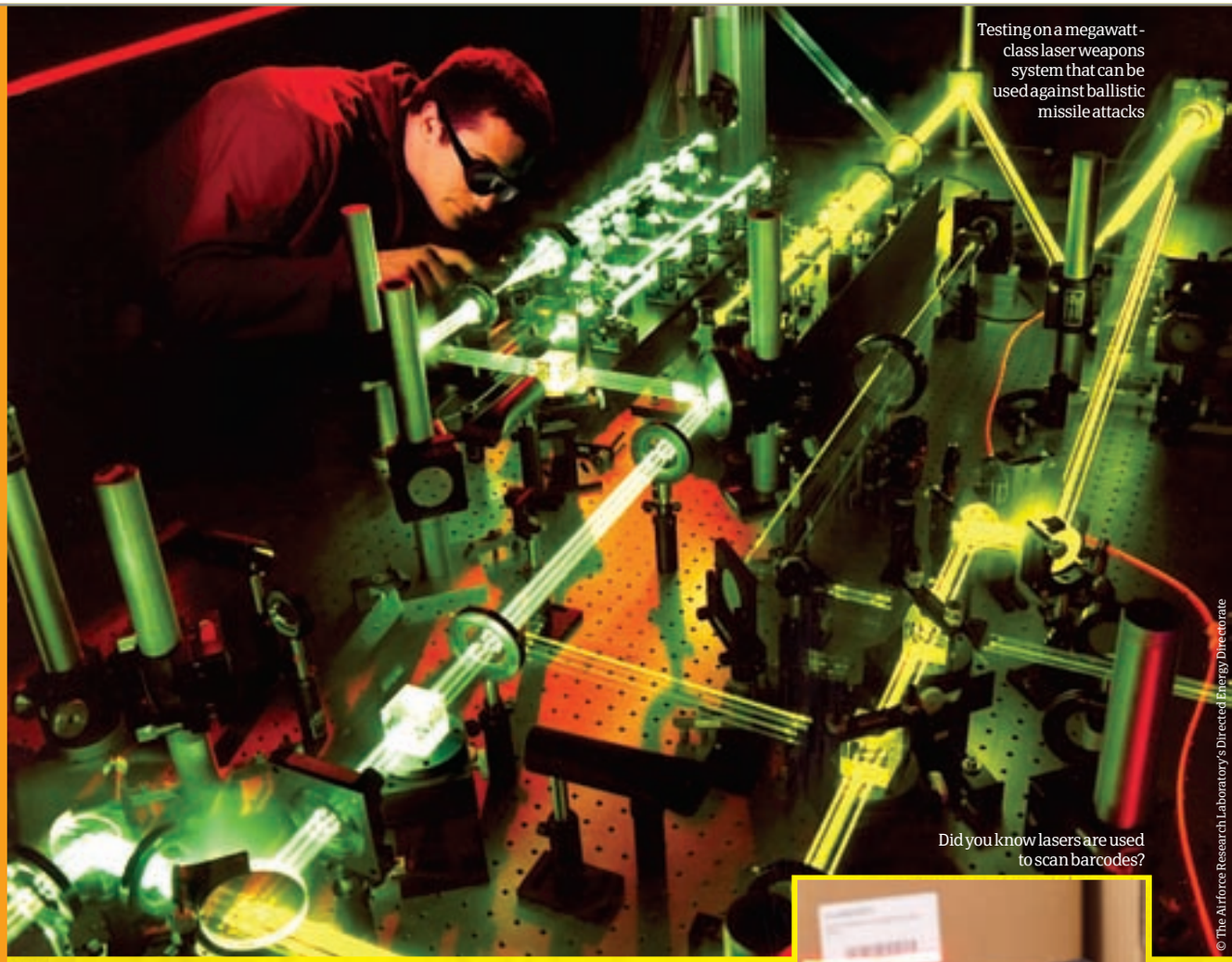
To celebrate 50 years of the laser, we decided to treat you to a four-page extravaganza on the subject, revealing how light energy can be put to use. We also found out more about our amazing bodies, including the vital functions of the liver as well as the mysterious internal clock ticking inside us. Liquid nitrogen is also a remarkable substance with some pretty unusual uses, so find out more on page 36. Plus discover how two liquids can be separated on page 30.

34 Performing CPR

35 Wind tunnels

37 Circadian rhythms

SCIENCE



Testing on a megawatt-class laser weapons system that can be used against ballistic missile attacks

© The Airforce Research Laboratory's Directed Energy Directorate

Did you know lasers are used to scan barcodes?

LASER POWER

50 years later, the laser is still powering technological breakthroughs

A pinpoint of super-concentrated light, hot enough to slice through steel like warm butter. An emerald-green beam bouncing across a matrix of mirrors. A silent weapon that can neutralise fast-moving targets from hundreds of kilometres away. Lasers are the fuel of science-fiction fantasies, but the reality is often more inspiring. Lasers can save lives through minimally invasive surgeries, they can transmit data at light speed and they can even probe the upper atmosphere for traces of climate-changing gas.

The story of the laser starts with the atom. Everything on our planet, from redwood trees to high-speed trains to pinky toes, is composed of atoms – 90 different varieties to be exact: carbon atoms, hydrogen atoms, even the occasional barium and antimony atoms. Each of these atoms is constantly on the move, with varying numbers of electrons whizzing around a nucleus.

In school, your science teacher displayed a diagram of an atom that looked like an archery target with perfectly circular electron orbits radiating out from the nucleus. We now understand that electrons don't travel in prescribed orbits, but swirl in chaotic clouds. Still, to understand lasers it's best to stick to the bull's-eye model.

Atoms get 'excited' (some easier than others) when you stimulate them with light, heat or electric current to certain atoms. This causes one or more of their electrons to jump to a higher orbital path. Picture the electron hopping one or more levels away from the nucleus.

5 TOP FACTS EVERYDAY LASER USE

Eye surgery
1 An ultraviolet laser can correct vision by gently vaporising the corneal tissue, which thins the cornea without penetrating the eye. The retina then receives a sharpened image.

Hair removal
2 Lasers can remove unwanted body hair by disabling hair follicles. The 'dark' follicle absorbs the light from the laser without burning the rest of the skin.

Teeth whitening
3 Laser whitening involves your teeth being coated with a bleaching chemical, which is then activated by the addition of laser light. A rubber dam is used to protect the gum area.

Tattoo removal
4 Ink from unwanted tattoos can be dissolved by the light energy of a laser. The ink absorbs the heat and is broken down and naturally absorbed by the skin, fading with time.

Laser printers
5 A laser printer's drum holds a positive electric charge. The laser 'draws' on the drum with a negative charge, creating an electrostatic image. Positively charged toner sticks to the drum.

DID YOU KNOW? *Apollo 14 put a laser reflector on the moon, enabling scientists to measure its distance from Earth to within 3cm*

Atoms don't stay excited for long, though, and the electron quickly drops back to its original orbit.

When that electron drops from an excited orbit to its ground state, energy is released in the form of a photon of light. This is how light bulbs and toasters work. Electric current excites the atoms in a metal filament. As the electrons in those atoms immediately return to their ground state, they release photons of light. We control the intensity and heat of this light by controlling the excitation level of the atoms.

A laser is a highly specialised form of light. Regular light is sloppy. It emits photons in all directions and at different wavelengths (colours). Laser light, on the other hand, is composed of photons that are not only the exact same wavelength and colour, but each photon 'waves' – or vibrates from crest to trough – at exactly the same time and travels in the exact same direction. This means that laser light is one colour (monochromatic), in sync (coherent) and tightly focused (collimated).

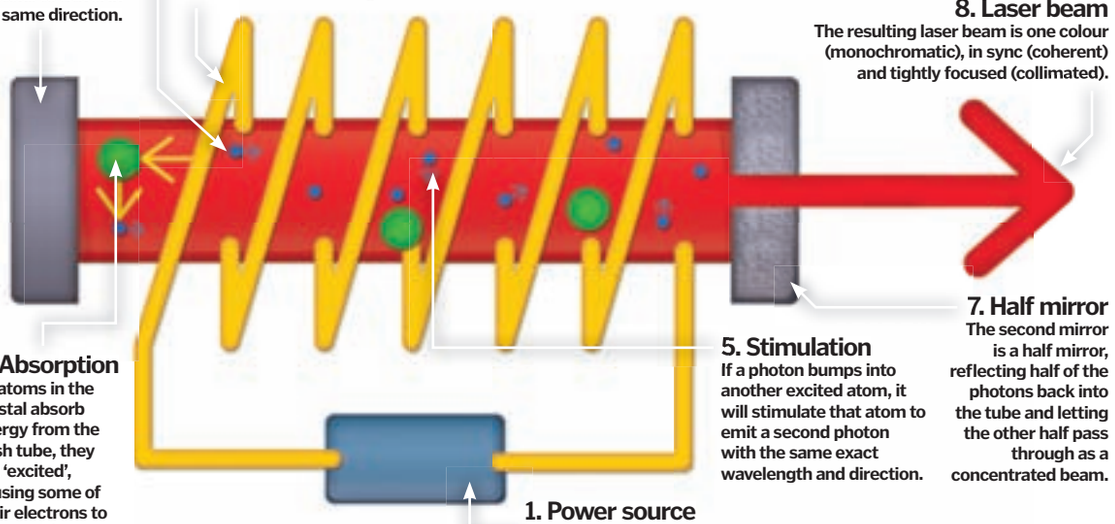
Laser light exhibits these properties because we tell it to. The word laser is actually an acronym for Light Amplification by Stimulated Emission of Radiation. Scientists have discovered specific atoms (in gas, liquid and solid states) that get excited when exposed to particular light, heat or electrical sources. Getting these atoms to produce photons is easy. The trick is focusing all those photons in the same direction. The answer, quite simply, is mirrors.

Picture a cylindrical tube filled with a gas. Put two mirrors on either end of the tube. When the gas in the tube gets excited it emits billions of photons in all directions. By sheer random luck, some of those photons will strike the mirrors at precisely a 90-degree angle, bouncing back to strike the opposite mirror. If one of these straight-shooting photons passes through another excited atom, it causes the atom to emit a new photon with the same exact wavelength and direction.

As more and more photons bounce off the mirrors, they create an intense, tightly focused beam of light tuned to a precise wavelength. The final trick is that one of the mirrors is half-silvered, reflecting only half of the photons and allowing the other half to pass through, creating the infamous laser beam.

Inside a laser

A ruby laser is one of the simplest and earliest examples of laser technology



6. Full mirror
When photons strike the full mirror at a 90-degree angle, they bounce straight back toward a second mirror, stimulating more photons to travel in the same direction.

4. Emission
Milliseconds later, the electrons return to their ground state, emitting energy as photons of light.

2. Flash tube
A flash tube coiled around the ruby crystal pumps the lasing material with flashes of intense light.

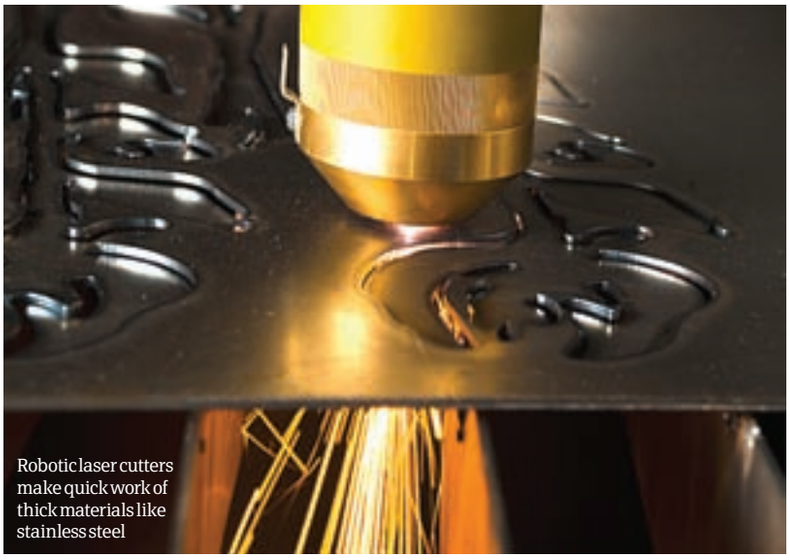
8. Laser beam
The resulting laser beam is one colour (monochromatic), in sync (coherent) and tightly focused (collimated).

7. Half mirror
The second mirror is a half mirror, reflecting half of the photons back into the tube and letting the other half pass through as a concentrated beam.

5. Stimulation
If a photon bumps into another excited atom, it will stimulate that atom to emit a second photon with the same exact wavelength and direction.

3. Absorption
As atoms in the crystal absorb energy from the flash tube, they get 'excited', causing some of their electrons to temporarily change orbit.

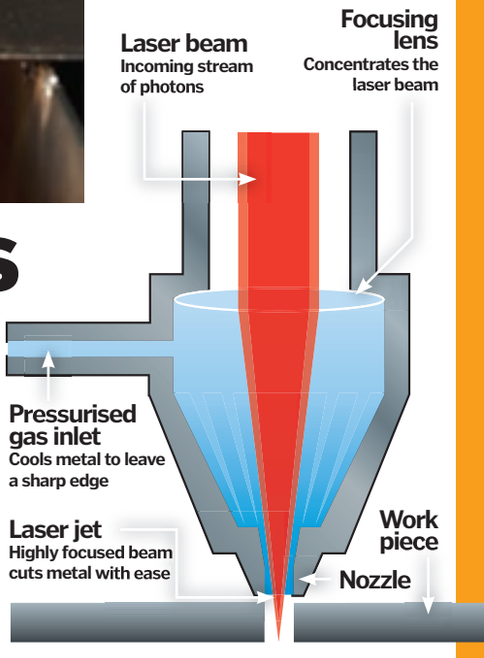
1. Power source
Inside a vacuum tube, the ruby 'lasing material' needs to be excited or 'pumped' by a light source.



Robotic laser cutters make quick work of thick materials like stainless steel

Inside a cutting laser

Powerful carbon dioxide infrared lasers are used for cutting metal with absolute precision



Industrial lasers

Precision-automated lasers are essential tools of modern manufacturing

Powerful lasers mounted on robotic arms can cut precision shapes out of thick sheets of acrylic, stainless steel, aluminium, titanium, even wood and granite. The product designs are drafted on computer software that controls the depth, power and meticulous movements of the laser. The lasing material of choice for high-power laser cutters is CO_2. A 400W CO_2 laser can slice through 3mm-thick stainless steel like it was warm butter. In fact, that's an excellent analogy. The heat from the highly focused laser melts through the steel rather than physically cutting it, leaving a smooth, unwarped edge. As seen in the diagram, a blast of pressurised gas instantly cools the freshly sliced edge.

"Dentists perform gum surgery, cavity removal and even whitening treatments using low-intensity diode lasers"

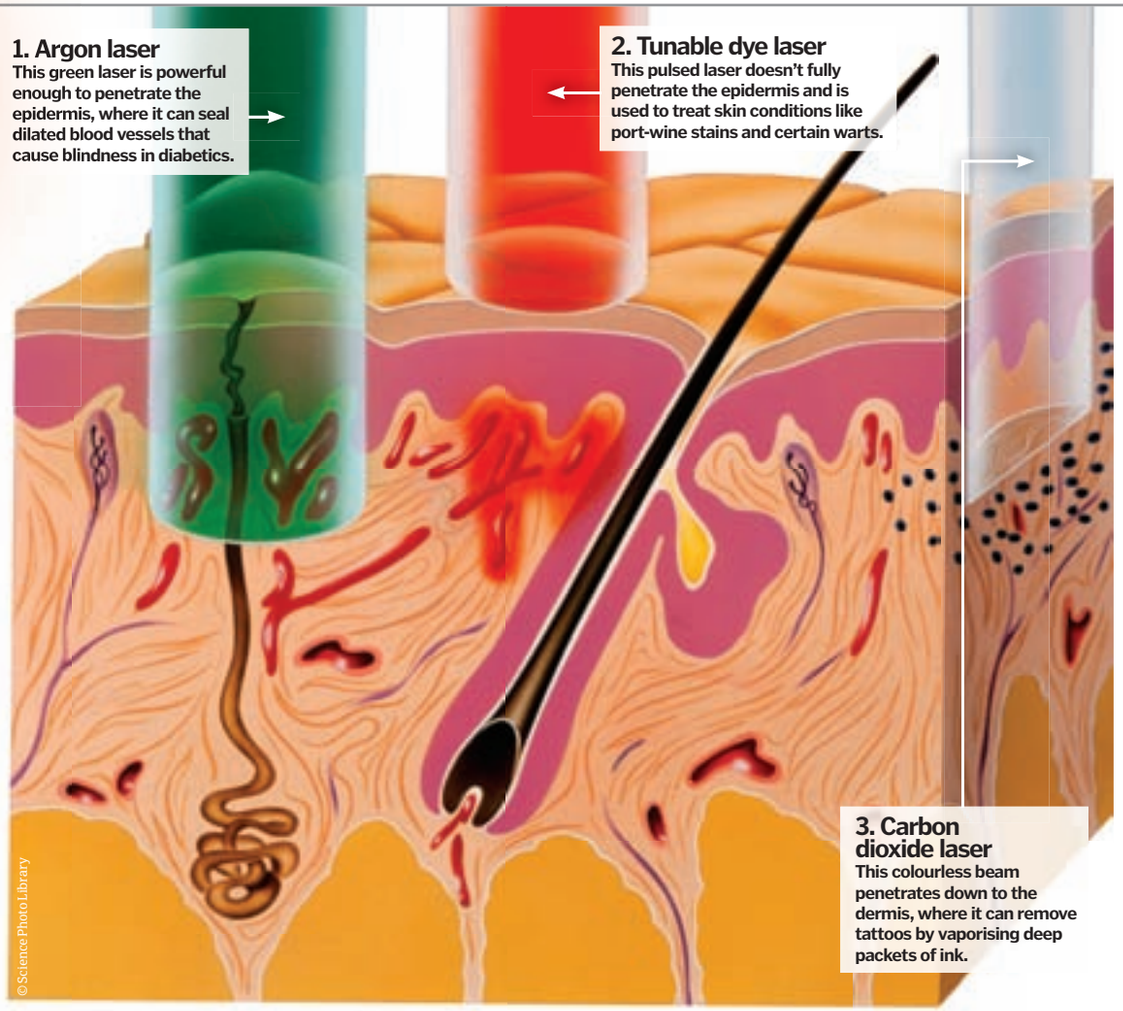
LIDAR

At a remote scientific outpost in Antarctica, a fluorescent green beam of laser light pierces the silent night sky. This is one of 20 climate research facilities spread out from pole to pole that use a technique called LIDAR to measure ozone levels in the upper atmosphere. LIDAR, short for Light Detection And Ranging, is the optical cousin of RADAR, Radio Detection And Ranging. Scientists aim the pulsed laser beams towards atmospheric gases as high as 95km and record the way the light scatters.

LIDAR is a form of long-distance spectroscopy, analysing the reflected light of atmospheric layers to identify their component gasses (including ozone and aerosols), temperature, water content and more. Interestingly, the very first lasers were built for radio astronomy. The brilliant green LIDAR laser isn't all that powerful – it's a 30-watt Nd:YAG laser compared with the 400-watt CO_2 models that cut through steel – but we don't want to slice planes in half, do we?

Beam me up (and down). Researchers study ozone levels in the upper atmosphere with LIDAR

© NASA

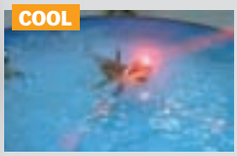


Medical lasers

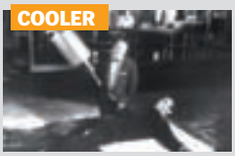
Replacing the scalpel and suture with a beam of hot light

For 40 years, lasers have been prized by surgeons, ophthalmologists, dentists and dermatologists for their precision. Surgeons use lasers to cut, cauterise, coagulate or even vaporise tissue. Wounds created by lasers heal quicker and with less chance of infection. Neurosurgeons can navigate deep, narrow approaches to brain tumours. The tools of choice are lower wattage versions of the same CO_2 lasers that cut through stainless steel. LASIK eye surgery uses pulses of laser light to reshape the cornea. Dentists perform gum surgery, cavity removal and even whitening treatments using low-intensity diode lasers. For hair removal, dermatologists use ruby, alexandrite and diode lasers whose heat is absorbed by dark hair follicles beneath the skin surface. For wrinkle therapy, a new 'fractional rejuvenation' technique creates tiny holes in the epidermal layer, stimulating the remaining tissue to tighten and produce more collagen.

Procedures like LASIK eye correction are performed in doctors' offices, not hospitals



1. Dr 'Frickin' Evil's sharks
"I have one simple request and that is to have sharks with frickin' laser beams attached to their heads." How hard can it be?



2. Goldfinger's laser room
Goldfinger's laser creeping ever closer to Bond's crown jewels is among the most memorable uses of lasers in Hollywood. Nightmare!

3. Death Star superlaser
The planet-busting superlaser built into the planetoid Death Star space station is by far the coolest laser in history.

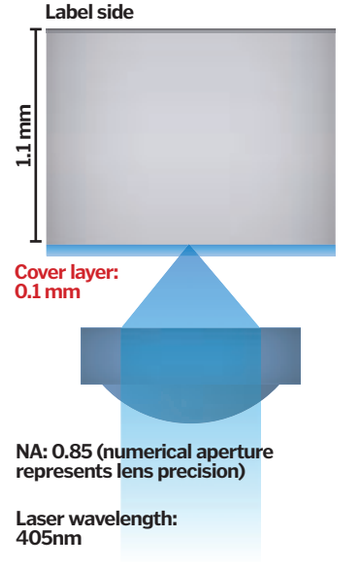
DID YOU KNOW? *The National Ignition Facility in California is the size of a football stadium – the largest laser in the world*

DVD/ Blu-ray

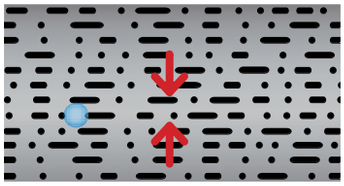
Digital technology packs the biggest Hollywood films into microscopic grooves

On an old-fashioned record player, a sensitive needle rides the groove in the vinyl to reproduce recorded wavelengths of sound. On digital media like CDs, DVDs and Blu-ray discs, the grooves are replaced by microscopic pits and the needle by a sharply focused laser beam. Digital music and video takes analogue sound light waves and converts them into binary code – a string of 1s and 0s. Each tiny pit on a CD or DVD represents a 0 and the smooth sections in between are 1s. A Blu-ray disc can hold five times as much data as a standard DVD because its pits are more tightly packed together (0.32 microns apart) and its laser – a 405nm blue-violet beam – can read much smaller surface data than the 650nm red lasers used for DVDs.

Blu-ray disc

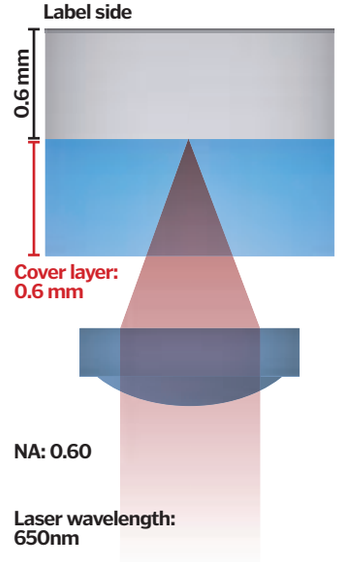


Track pitch: 0.32um
The small wavelength of a blue-violet laser (hence Blu-ray) offers greater precision capable of reading closely packed pits.

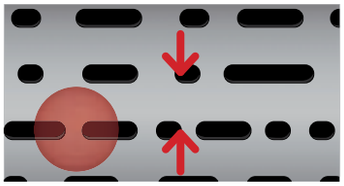


Capacity: 25GB

DVD

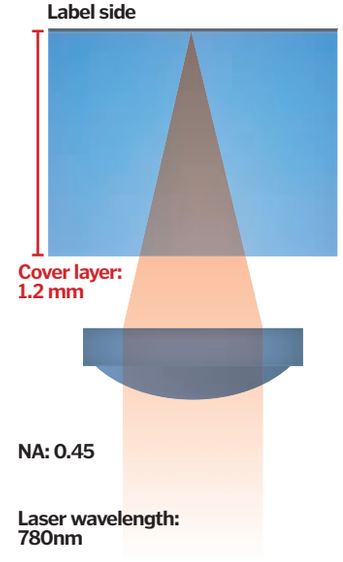


Track pitch: 0.74um
Regular DVDs and CDs use red lasers with much larger wavelengths that cannot read closely packed data.

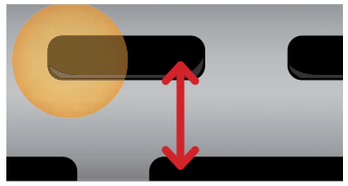


Capacity: 4.7GB

CD



Track pitch: 1.60um
Because CD data is written all the way through a disc (not just the bottom layer as on Blu-ray), refraction can reduce quality.



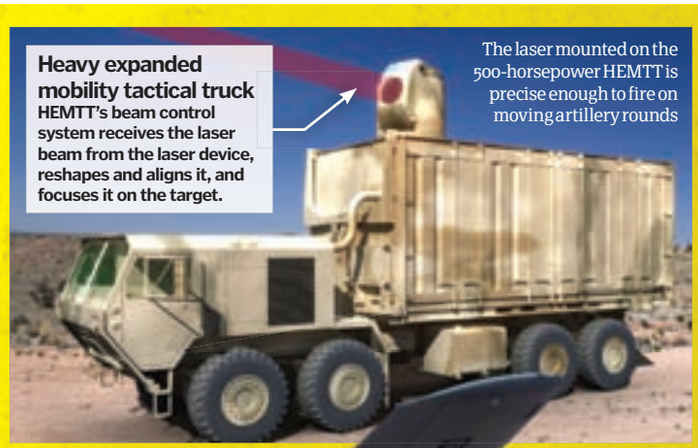
Capacity: 700MB

Lasers as weapons

Light years away from the Death Star, modern laser weapons still pack a blast

While the handheld Blaster guns of *Star Wars* are still far, far away, vehicle-mounted lasers are ready for combat. In early 2010, the US Army launched a short-range ballistic missile off the coast of California to test Boeing's YAL-1 airborne laser, a high-energy chemical oxygen iodine laser (codename COIL) mounted to the nose of a modified 747. Within seconds of the missile's launch, the 747 used a pair of low-intensity lasers to locate and track the weapon's trajectory. Less than two minutes after the missile launch, the 747 fired its megawatt-class laser, melting the missile's critical thrusters and sending it crashing to the sea. Laser weapons don't 'blow stuff up', but use concentrated heat to disable the target.

Boeing also recently announced the fabrication of a truck-mounted laser that has successfully disabled unmanned aircraft and will be used to instantly detect and counter artillery and mortar attacks, as well as neutralise roadside bombs. As for handheld lasers, the best the military can muster is the PHASER (personal halting and stimulation response), a non-lethal weapon introduced in 2005 that temporarily blinds its targets like a high-powered flashlight. Not exactly the stuff of science fiction...



Heavy expanded mobility tactical truck
HEMTT's beam control system receives the laser beam from the laser device, reshapes and aligns it, and focuses it on the target.

The laser mounted on the 500-horsepower HEMTT is precise enough to fire on moving artillery rounds

Advanced tactical laser
The ATL consists of a high-energy chemical laser, beam control system and battle manager, offering precision in-flight engagement with targets on the ground.

Boeing's Advanced Tactical Laser (ATL) uses a lower-powered beam to strike targets within ten miles

"The process is used widely in refineries"

Distillation

An ancient method for separating and purifying liquids

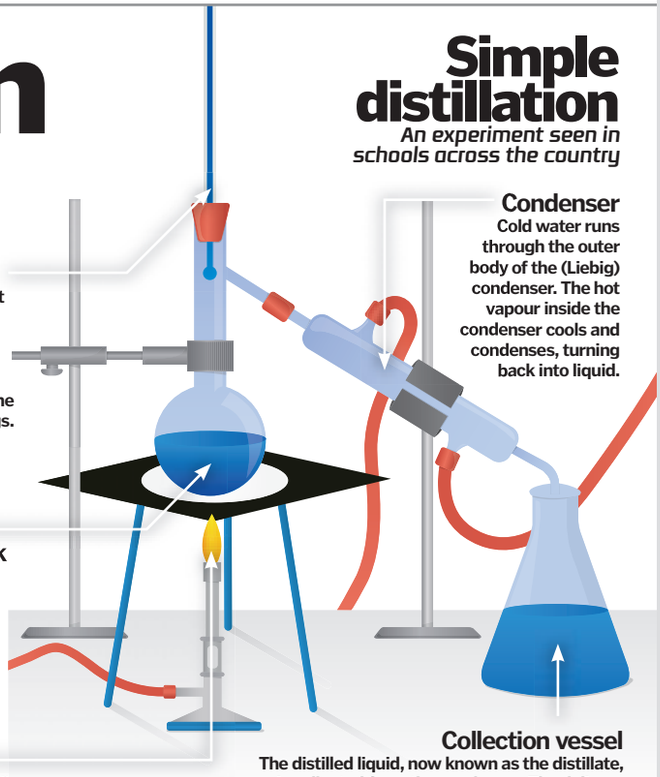
At its simplest, distillation is the process of separating liquids containing two or more components from each other. They are separated through the process of boiling the liquid in a flask and cooling the resulting vapour using a condenser. It is based on the principle that the substances in the liquid have different levels of volatility.

The components of the liquid with the lowest boiling points will produce the most vapour and will travel into the condenser. Therefore, the liquid distillate collected from the condenser will consist of the most volatile components while the remaining liquid in the flask will contain the less volatile components.

Water was purified through distillation as early as AD 200. The process is now used widely in refineries, manufacturing and in the production of pharmaceuticals, alcoholic spirits and perfumes.

Simple distillation

An experiment seen in schools across the country



Thermometer
This enables the heat of the vapour to be monitored. Suitable adjustments to the heat source can be made in relation to the temperature readings.

Condenser
Cold water runs through the outer body of the (Liebig) condenser. The hot vapour inside the condenser cools and condenses, turning back into liquid.

Round-bottomed flask
The tall rectifying column of the flask helps the boiling liquid to condense before leaving the flask.

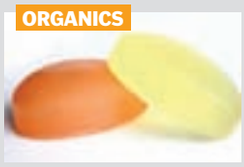
Heat source
Here a Bunsen burner heats the liquid to boiling point.

Collection vessel
The distilled liquid, now known as the distillate, is collected from the condenser. The delivery tubing usually has a vent to allow for expanding gases produced by the heat of the apparatus.

Head to Head DISTILLATION

1. Fractional
This forces liquid with very close volatile points through a fractionating column. This allows the most volatile components to be systematically condensed.

2. Dry
Involves heating solids like wood or coal to produce a gas. The condensed gas results in the distillation of liquid fuel.



3. Steam
Volatile organic material is subjected to pressurised steam. The resulting steam and oil vapours are condensed and a separator removes the oils.

5 TOP FACTS DONATED BLOOD

Anaemia
1 One quarter of blood transfusions are given to patients with anaemia, whose blood levels have been dropping slowly over time due to diseases like cancer.

Haematology
2 Some patients have blood disorders where their own red blood cells are deficient, such as in sickle cell disease or red cells destroyed at a high rate called haemolysis.

Orthopaedics
3 In orthopaedic surgery – such as spinal fusion and hip arthroplasty – blood is lost during the operation. This is common with large joint replacement surgery.

Gastrointestinal bleeding
4 Blood loss from the gastrointestinal tract, such as stomach ulcers and colorectal cancer, accounts for 11 per cent of all blood transfusions.

Childbirth
5 The fifth most common cause of blood transfusion is during or following traumatic childbirth. Normally blood loss during childbirth is less than 600ml.

DID YOU KNOW? *The first ever successful blood transfusion was performed on a dog in 1665 by Richard Lower*

No one can get a transfusion unless blood donors keep donating

Blood transfusions

Whether it's a patient haemorrhaging to death or a 'top up' for life-long diseases, blood transfusions are vital procedures

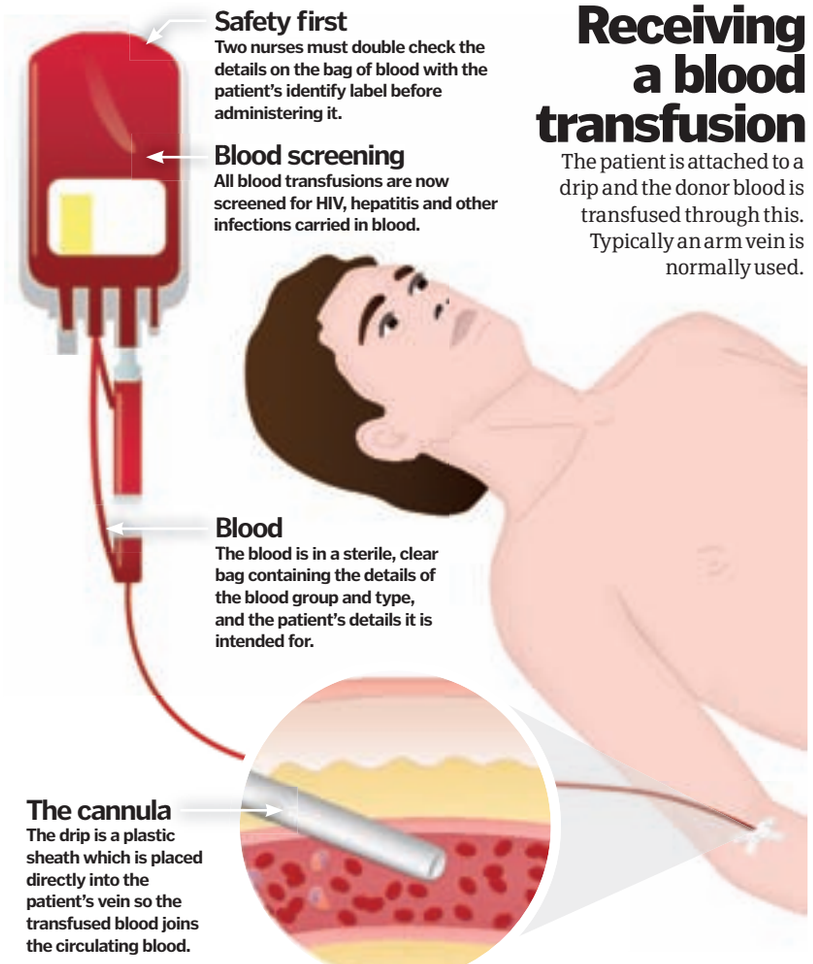
A blood transfusion takes place when a patient is given components of blood from a donor when their own blood levels are too low. Having enough blood is essential because it carries oxygen around the body and returns carbon dioxide to the lungs to be exhaled as a waste product.

When a doctor decides a patient needs blood, they are 'cross-matched' with donor blood. A few millilitres of their blood is collected into a small bottle which must be hand-labelled to prevent confusion between patients. In the lab the blood is matched with donor blood of the same group (either A, B or O). The unit of donor blood is then transfused via a drip into the patient's vein over two to three hours.

During this time the nurse keeps close observation of the patient to look for transfusion reactions. These can be mild (such as a fever, chills or a rash), which are solved by slowing down the rate of flow, to severe, life-threatening allergic reactions.

Receiving a blood transfusion

The patient is attached to a drip and the donor blood is transfused through this. Typically an arm vein is normally used.

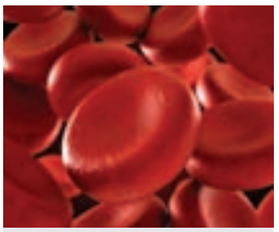


Safety first
Two nurses must double check the details on the bag of blood with the patient's identify label before administering it.

Blood screening
All blood transfusions are now screened for HIV, hepatitis and other infections carried in blood.

Blood
The blood is in a sterile, clear bag containing the details of the blood group and type, and the patient's details it is intended for.

The cannula
The drip is a plastic sheath which is placed directly into the patient's vein so the transfused blood joins the circulating blood.



What's in your blood?

Red blood cells
Red blood cells are the most abundant cells in blood and give it a red colour. They carry oxygen from the lungs around the body, bound to a protein called haemoglobin.

Plasma
Plasma is a straw-coloured watery fluid that carries all of the cells and proteins in blood, including the vital clotting factors.

Platelets
Platelets are tiny fragments of blood that are crucial in stopping bleeding, along with clotting factors, by forming a platelet plug.

White blood cells
These are your infection-fighting cells; they circulate in the blood so they can quickly multiply and be transported to an area where there's an infection flaring.

Lymphocytes
Lymphocytes are a type of white blood cell that directs the body's immune system. They have a memory for invading bacteria and viruses.

The ABO blood groups

We all belong to one of four blood types (below). Different antigens present on the surface of red blood cells identify to which group you belong. A patient must be receive blood with the correct antigens else their immune system will recognise that the red blood cells are foreign cells and will attack.

A – A antigens on red blood cells and anti-B antibodies in plasma
B – B antigens on red blood cells and anti-A antibodies in plasma
AB – A and B antigens on red blood cells and no antibodies in plasma
O – no antigens on red blood cells and anti-A and anti-B antibodies in plasma

"It is the second most complex organ after the brain"

How the liver w

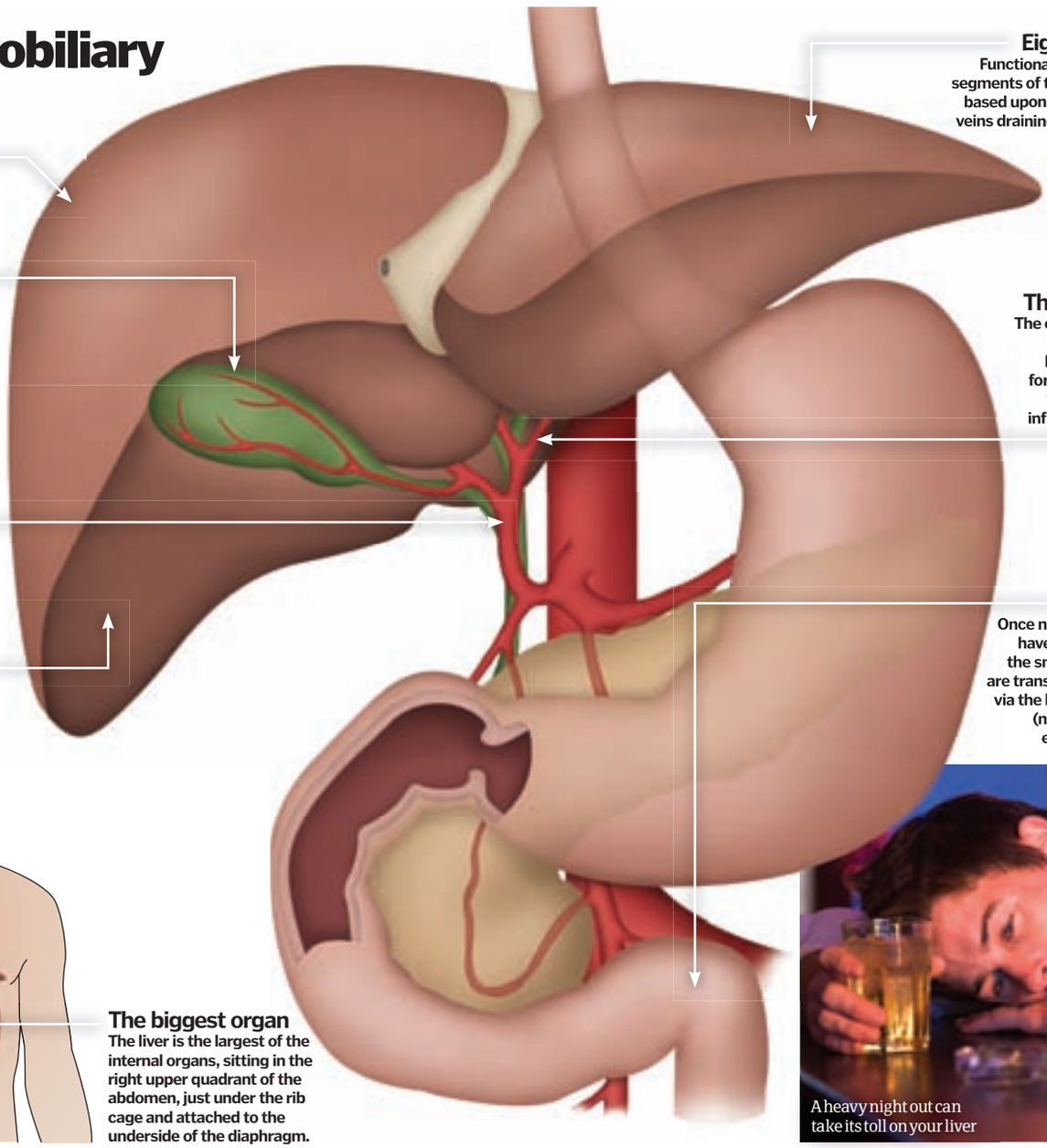
The human liver is the ultimate multitasker – it performs many different functions all at the same time without you even asking

The liver is the largest internal organ in the human body and amazingly has over 500 different functions. In fact, it is the second most complex organ after the brain and is intrinsically involved in almost every aspect of the body's metabolic processes. The liver's main functions are energy production, removal of harmful substances and the production of crucial proteins. These tasks are carried out within liver cells, called hepatocytes, which sit in complex arrangements to maximise efficiency.

The liver is the body's main powerhouse, producing and storing glucose as a key energy source. It is also responsible for breaking down complex fat molecules and building them up into cholesterol and triglycerides, which the body needs but in excess are bad. The liver makes many complex proteins, including clotting factors which are vital in arresting bleeding. Bile, which helps digest fat in the intestines, is produced in the liver and stored in the adjacent gallbladder.

The liver also plays a key role in detoxifying the blood. Waste products, toxins and drugs are processed here into

The hepatobiliary region



Two halves
The liver is anatomically split into two halves: left and right. There are four lobes, and the right lobe is the largest.

The gallbladder
The gallbladder and liver are intimately related. Bile, which helps digest fat, is produced in the liver and stored in the gallbladder.

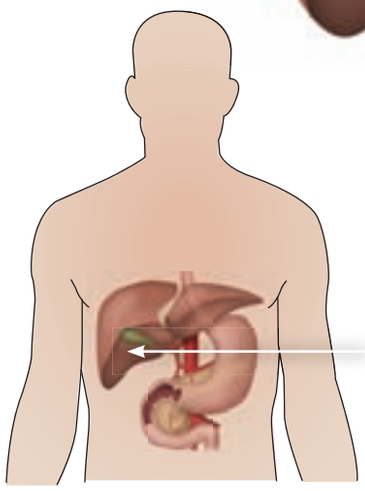
The common bile duct
This duct is small, but vital in the human body. It carries bile from the liver and gallbladder into the duodenum where it helps digest fat.

Feel your liver
Take a deep breath in and feel just under the right lower edge of your ribs – in some people the lower edge of the liver can be felt.

Eight segments
Functionally, there are eight segments of the liver, which are based upon the distribution of veins draining these segments.

The portal triad
The common bile duct, hepatic artery and hepatic portal vein form the portal triad, which are the vital inflows and outflows for this liver.

Digestion
Once nutrients from food have been absorbed in the small intestine, they are transported to the liver via the hepatic portal vein (not shown here) for energy production.



The biggest organ
The liver is the largest of the internal organs, sitting in the right upper quadrant of the abdomen, just under the rib cage and attached to the underside of the diaphragm.

A heavy night out can take its toll on your liver

5 TOP FACTS LIVER

Ice cold liver
1 Polar bear liver is an incredibly rich source of vitamin A – so much so that Arctic explorers have actually died from eating it, as it can cause vitamin A poisoning.

Liver transplants
2 In the UK 600-700 liver transplants are performed each year. The donor liver can be preserved in a solution for up to 24 hours before it is transplanted.

Maximising numbers
3 Ways around the shortage of donor livers include splitting an adult liver in half and giving it to two children, and live-donor transplantation (a portion of a relative's liver is transplanted).

Largest organ in the body
4 The liver is the largest internal organ in the human body and in most animals' bodies too. It typically has the same shape as a human's, except in snakes where it is elongated.

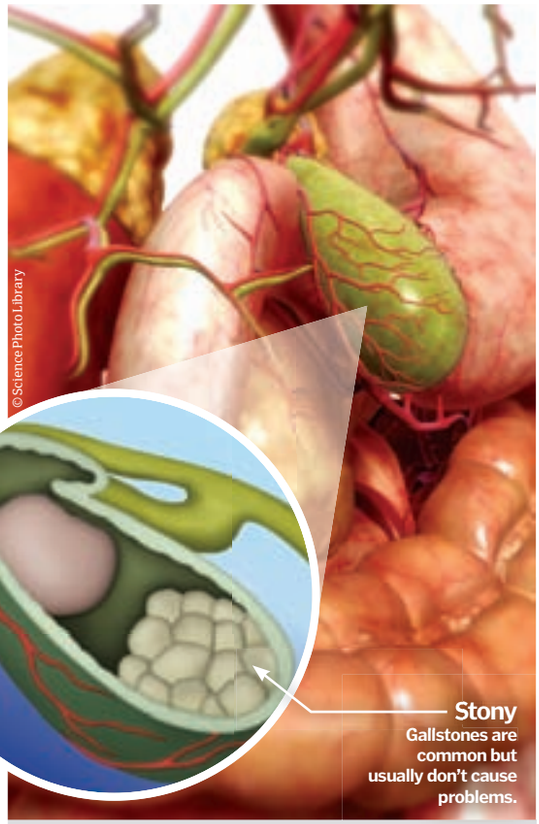
Greek mythology
5 Wise Titan Prometheus was chained for eternity to a rock in the Caucasus, where an eagle would eat at his liver and each day the liver would be renewed!

DID YOU KNOW? *The liver can regenerate itself. If up to 75 per cent of the liver is removed, it can grow back to restore itself*

works

forms which are easier for the rest of the body to use or excrete. The liver also breaks down old bloods cells, produces antibodies to fight infection and recycles hormones such as adrenaline. Numerous essential vitamins and minerals are stored in the liver: vitamins A, D, E and K, iron and copper.

Such a complex organ is also unfortunately prone to diseases. Cancers (most often metastatic from other sources), infections (hepatitis) and cirrhosis (a form of fibrosis often caused by excess alcohol consumption) are just some of those which can affect the liver.



The gallbladder

Bile, a dark green slimy liquid, is produced in the hepatocytes and helps to digest fat. It is stored in a reservoir which sits on the under-surface of the liver, to be used when needed. This reservoir is called the gallbladder. Stones can form in the gallbladder (gallstones) and are very common, although most don't cause problems. In 2009, just under 60,000 gallbladders were removed from patients within the NHS making it one of the most common operations performed; over 90 per cent of these are removed via keyhole surgery. Most patients do very well without their gallbladder and don't notice any changes at all.

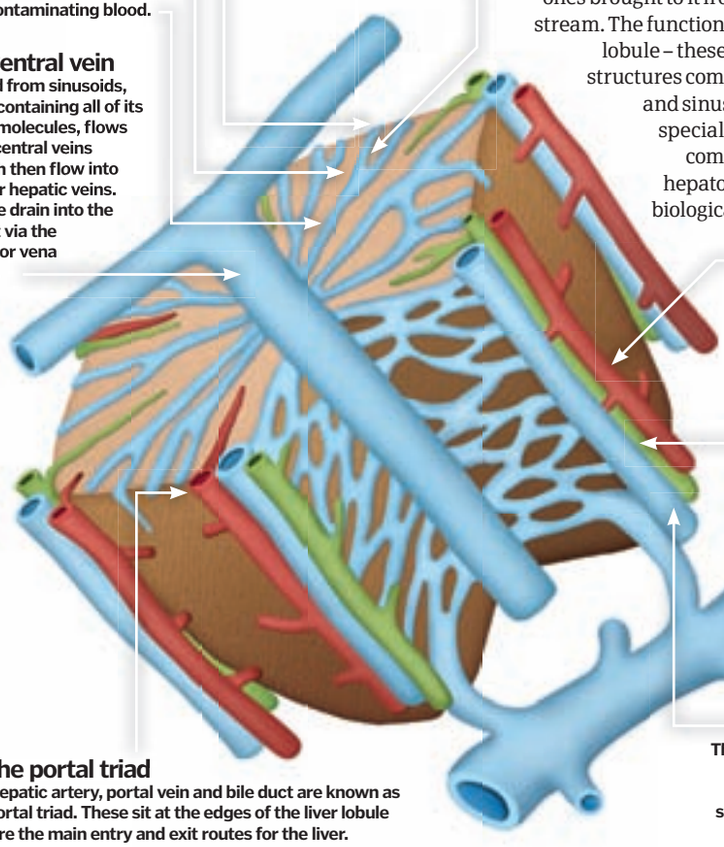
A high demand organ

The liver deals with a massive amount of blood. It is unique because it has two blood supplies. 75 per cent of this comes directly from the intestines (via the hepatic portal vein) which carries nutrients from digestion, which the liver processes and turns into energy. The rest comes from the heart, via the hepatic artery (which branches from the aorta), carrying oxygen which the liver needs to produce this energy. The blood flows in tiny passages inbetween the liver cells where the many metabolic functions occur. The blood then leaves the liver via the hepatic veins to flow into the biggest vein in the body – the inferior vena cava.

Liver lobules

The functional unit which performs the liver's tasks

The liver is considered a 'chemical factory,' as it forms large complex molecules from smaller ones brought to it from the gut via the blood stream. The functional unit of the liver is the lobule – these are hexagonal-shaped structures comprising of blood vessels and sinusoids. Sinusoids are the specialised areas where blood comes into contact with the hepatocytes, where the liver's biological processes take place.



1. The lobule
This arrangement of blood vessels, bile ducts and hepatocytes form the functional unit of the liver.

2. The hepatocyte
These highly active cells perform all of the liver's key metabolic tasks.

3. Sinusoids
These blood filled channels are lined by hepatocytes and provide the site of transfer of molecules between blood and liver cells.

4. Kupffer cells
These specialised cells sit within the sinusoids and destroy any bacteria which are contaminating blood.

5. Hepatic artery branch
Blood from here supplies oxygen to hepatocytes and carries metabolic waste which the liver extracts.

6. Bile duct
Bile, which helps digest fat, is made in hepatocytes and secreted into bile ducts. It then flows into the gallbladder for storage before being secreted into the duodenum.

7. Portal vein
This vein carries nutrient-rich blood directly from the intestines, which flows into sinusoids for conversion into energy within hepatocytes.

8. The portal triad
The hepatic artery, portal vein and bile duct are known as the portal triad. These sit at the edges of the liver lobule and are the main entry and exit routes for the liver.

9. Central vein
Blood from sinusoids, now containing all of its new molecules, flows into central veins which then flow into larger hepatic veins. These drain into the heart via the inferior vena cava.

"On TV, CPR is like the Fonz hitting the jukebox on Happy Days"

CPR, step by step

Authorities differ on exact recommendations. The procedure described here is based on guidelines from the Resuscitation Council (UK). To ensure you administer CPR correctly, it's essential to take a training course with a qualified instructor. If you believe someone has suffered cardiac arrest, gently shake their shoulders and shout, "Are you okay?" If the victim responds, he has not suffered cardiac arrest and does not need CPR. If the victim doesn't respond, yell for help.

How CPR works

The real thing isn't exactly the Hollywood version, but it's no less dramatic

On television, cardiopulmonary resuscitation (CPR) is like the Fonz hitting the jukebox on *Happy Days*: whack a dying person in the right spot and his heart will start beating again. However, this hardly ever works in real life, and it isn't actually the point of administering CPR. The real goal here is to buy some valuable time until it's possible to revive a normal heart beat, typically using an electric jolt from a defibrillator.

The cells in your body need oxygen to convert food into usable energy. Your heart delivers the goods. It pumps oxygenated blood from the lungs out to the body, and pumps deoxygenated blood back to the lungs. If your heart isn't pumping sufficient blood – a condition called cardiac arrest – your body's cells will fail. Most significantly, your brain cells (neurons) will start dying four to six minutes after cardiac arrest begins. Ten minutes without resuscitation efforts and the chances of revival are almost nil.

The basic idea of CPR is to hold off death by manually forcing the victim's lungs and heart to provide oxygenated blood to the brain. Exhaling air into the victim's lungs provides the necessary oxygen, and regularly compressing the chest forces the heart to pump blood.

CPR for children and babies

Because cardiac arrest in children and babies is more likely to be due to a lack of oxygen than a heart condition, quick action and increased attention is essential. Experts recommend adjusting technique to account for smaller body size.

First, perform CPR for one minute before seeking help. Begin with five rescue breaths. For infants less than a year old, cover the mouth and nose with your mouth. Since an infant's lungs are small, less air is required than in adult CPR. After five rescue breaths, begin chest compressions.

For infants, use two fingers to push down on the chest, just below an imaginary line running between the nipples. For children between ages one and puberty, use the heel of a single hand. Compress the chest to 1/3 of its depth. After 15 compressions, perform two rescue breaths, then repeat the cycle.

Disclaimer

CPR should only be performed in emergencies. These instructions are a guide to how CPR works – professional first aid training is always recommended.

Head to Head WIND TUNNELS

BIGGEST

1. NASA's Ames Research Center
Silicon Valley, California
The world's largest wind tunnel has a test section 120ft wide and 80ft high – enough to test a full-sized Boeing 737.

FASTEST

2. LENS-X wind tunnel Calspan University, New York
The world's fastest wind tunnel can momentarily deliver airflow at Mach 30 and was used to test NASA's Orion spacecraft.

LONGEST SERVING

3. Langley, Virginia
Opened in 1931, the world's first wind tunnel for testing full-scale aircraft remained in operation for 78 years until September 2009.

DID YOU KNOW? *The pressure the wind puts on an object can be measured with fluorescent paint*

Wind tunnels

Allowing engineers to test aircraft designs in the lab, wind tunnels are invaluable to scientific research

A wind tunnel simulates in a laboratory the flow of air around, for example, an aeroplane or a building. This allows designers to work out the impact this airflow will have on the finished product and make cars and planes more aerodynamic and structures more wind resistant.

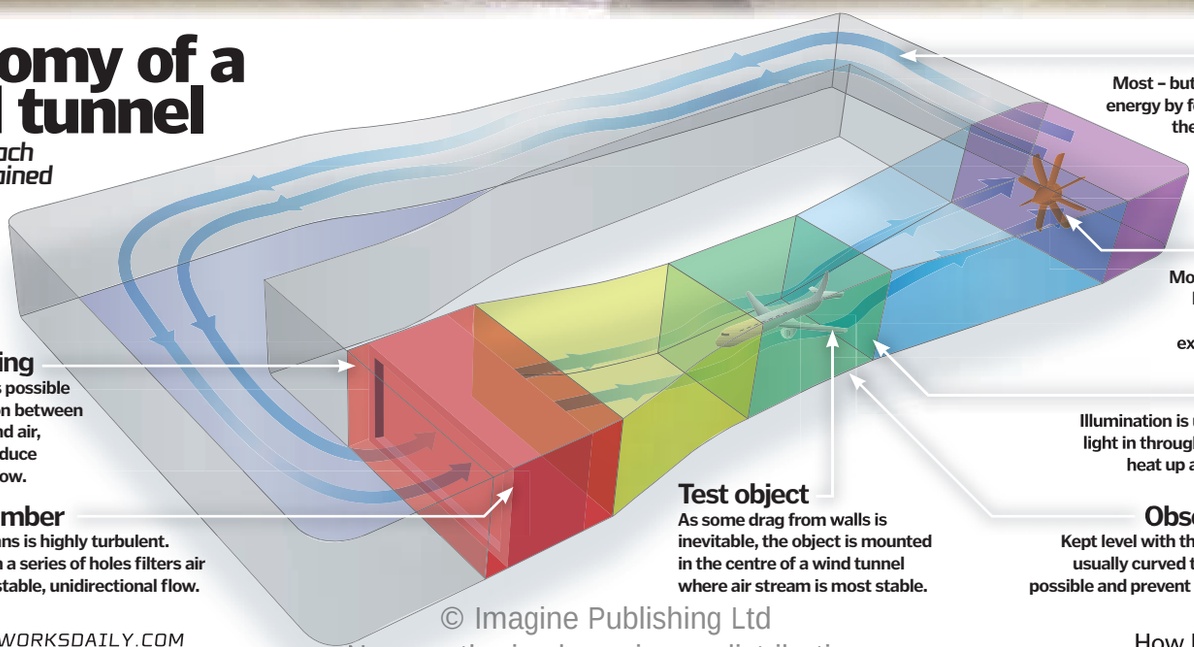
Wind tunnels are large circular tubes through which air is blown in one direction by giant fans: the test object – usually a scale model of the actual design – is mounted in the centre. In the case of an aircraft or a plane, in reality the object will be moving while the air stays still, but this doesn't matter as long as the relative velocity between the air and the object is the same. An enclosed cylinder is needed to allow for uniform airflow in one direction (known as laminar flow), simulating the airflow past a plane moving in a straight line or the wind hitting a skyscraper.

Testing in the supersonic wind tunnel at NASA's Lewis Flight Propulsion Laboratory

Both photographs © NASA

Anatomy of a wind tunnel

The role of each section explained



Closed loop
Most – but not all – wind tunnels save energy by feeding the moving air from the exhaust back to the input.

Fans
Most wind tunnels use fans or banks of fans, although the very fastest use explosive expansion of compressed air.

Lighting
Illumination is usually provided by shining light in through windows – lighting would heat up air and produce turbulence.

Observation windows
Kept level with the inside of wind tunnel and usually curved to keep inside as smooth as possible and prevent introduction of turbulence.

Test object
As some drag from walls is inevitable, the object is mounted in the centre of a wind tunnel where air stream is most stable.

Internal casing
Kept as smooth as possible to minimise friction between the wind tunnel and air, which would introduce turbulence to airflow.

Settling chamber
Air produced by fans is highly turbulent. Metal grating with a series of holes filters air current to create stable, unidirectional flow.

"Nitrogen gas has to be cooled to -195.8°C"

Liquid nitrogen

A great way to stop your enemies in their tracks, just like in *Terminator 2*

The substance that's deadly enough to stop a Terminator

Nitrogen gas makes up around 78 per cent of the Earth's atmosphere – however liquid nitrogen is uncommon. This is because nitrogen gas has to be cooled to -195.8°C before it is transformed into a completely colourless liquid. By contrast, water becomes a liquid below 100°C.

Liquid nitrogen absorbs lots of heat when it evaporates so it's useful for rapidly cooling things like food. Quick cooling means large ice crystals don't have time to grow, burst cells and damage food quality. Since nitrogen is inert – it reacts with few chemicals – it's safe to immerse food and it displaces the oxygen that harmful bacteria need to grow.

When liquid nitrogen evaporates, it creates around 700 times its volume in gas and pushes aside the air surrounding it. If there's not enough ventilation in a room, the nitrogen can displace all the oxygen and suffocate anyone inside.

DID YOU KNOW?

In *Terminator 2: Judgment Day*, (Skynet Edition) is available on Blu Ray for £8 at www.amazon.co.uk

5 TOP FACTS
EXCITING USES OF NITROGEN

1 Making ice cream
Ice cream frozen with liquid nitrogen is smooth, creamy, light in texture and a litre can be made in 30 seconds. Fans of this technique include world-class chef Heston Blumenthal.

2 Preserving specimens
Rapid freezing can be used to preserve tissue such as blood and bone marrow. Other items that can also be stored in liquid nitrogen include animal embryos, bacteria, and fungi.

3 Removing warts
Freezing off warts and verrucas using liquid nitrogen is a common, quick procedure that's simple enough to do in a doctor's office. The extreme cold destroys the unwanted skin cells.

4 Recycling tyres
Rubber tyres are built to be durable, making them hard to destroy. Freezing makes them brittle so they can be smashed into 'crumbs' for uses like building running tracks.

5 Powering cars
Liquid nitrogen could be a futuristic fuel. As it rapidly changes from a liquid to a gas, the resulting gas flow could power a turbine and turn car wheels.

5 TOP FACTS CIRCADIAN RHYTHMS

1 Jet lag
Time zone changes can often disrupt circadian rhythms. Your body clock may be out of sync with your wristwatch, but it will reset itself after a few days.

2 Mental state
Health conditions such as depression, bipolar disorder and seasonal affective disorder (SAD) are all associated with abnormalities in circadian rhythms.

3 Latin name
With these rhythms known to occur approximately every 24 hours, the phrase 'circadian' stems from Latin for 'circa', which means 'about', and 'diem', which means 'day'.

4 The living clock
In the 18th Century, a botanist called Carolus Linnaeus is said to have invented a living clock. His garden could help him tell the time based on the flowers he planted.

5 Time to take your pills
Doctors tell you to take medicine at a prescribed time because the body clock can affect their effectiveness. Aspirins function better when taken in the morning.

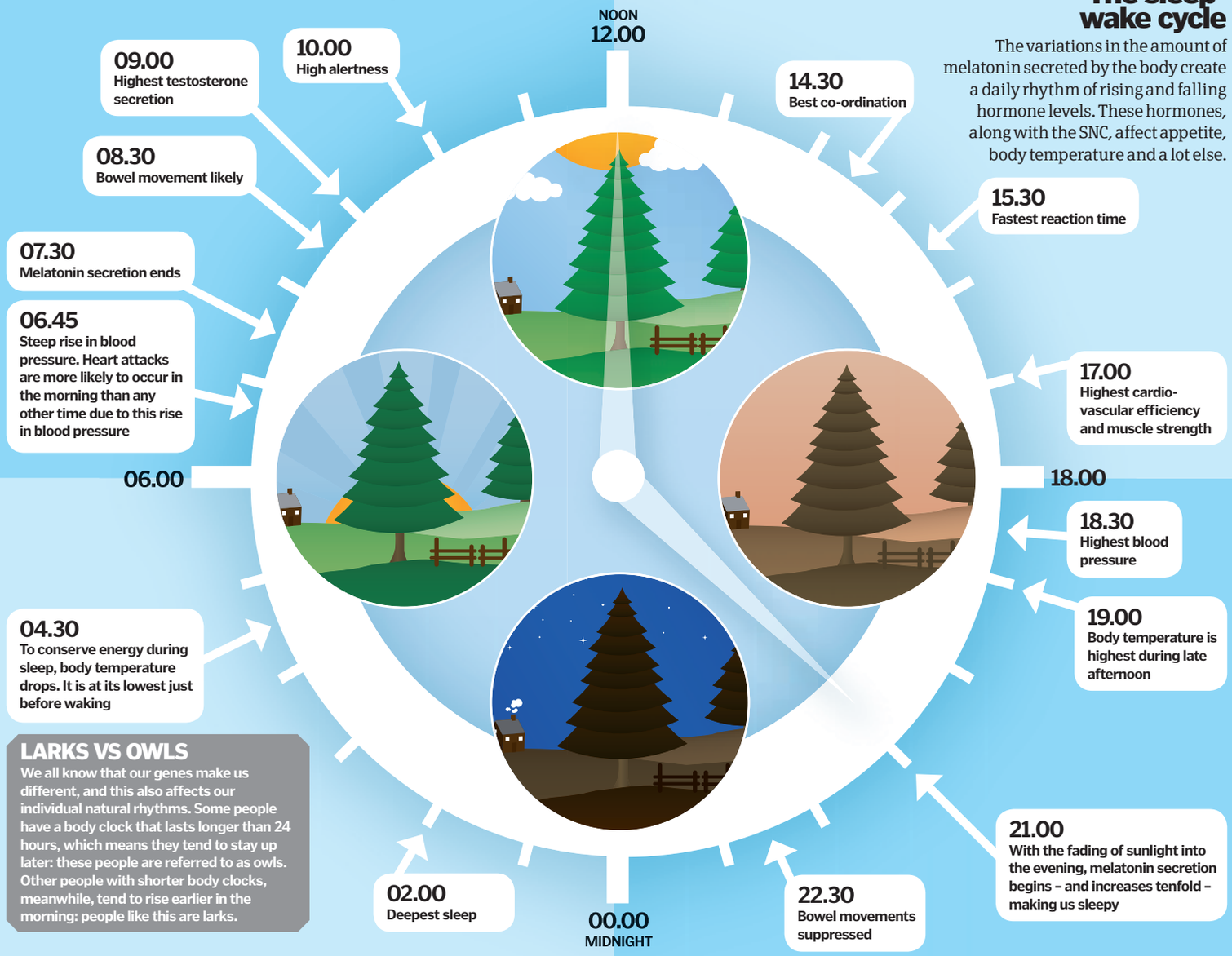
DID YOU KNOW? *The pineal gland, located near the centre of the brain, is about 8mm long and shaped like a pine cone*

Circadian rhythms

How does our internal body clock tell us when to sleep?

The sleep-wake cycle

The variations in the amount of melatonin secreted by the body create a daily rhythm of rising and falling hormone levels. These hormones, along with the SNC, affect appetite, body temperature and a lot else.

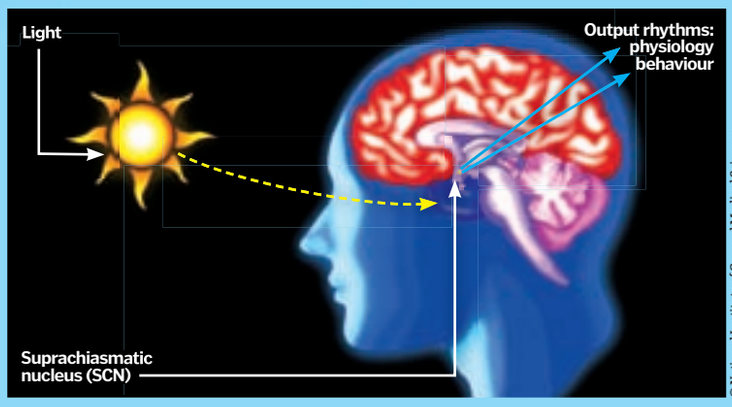


LARKS VS OWLS

We all know that our genes make us different, and this also affects our individual natural rhythms. Some people have a body clock that lasts longer than 24 hours, which means they tend to stay up later: these people are referred to as owls. Other people with shorter body clocks, meanwhile, tend to rise earlier in the morning: people like this are larks.

Circadian rhythms are biological changes that occur at roughly 24-hour intervals, whether we're aware of the time on our watch or not. These changes, which are controlled by internal biological time-keeping systems, affect us physically, mentally and behaviourally.

Located behind the eyes in the hypothalamus is a region of the brain called the suprachiasmatic nucleus. No larger than a grain of rice, the SCN is a kind of master body clock that controls all our other internal clocks, which in turn control our circadian rhythms, or daily wake-sleep cycles. Circadian rhythms respond mainly to light and dark cues but even if the body was monitored under conditions devoid of day or night signals, our circadian rhythms still cycle in a period of around 24 hours. The retina in the eye senses light level information, which is relayed to the SCN, which sends a signal to the pineal gland. This pea-sized gland, located beneath the thalamus, is responsible for the secretion of melatonin – a hormone that tells the body to sleep – and so at night when light levels fall, the production of melatonin increases, telling us to head to bed...



This month in **Technology**

What are these enormous vehicles doing in the technology section, you ask? Surely they should be parked two sections over in the transport section? No. They shouldn't. After much debate and consideration at many meetings it was decided that, due to the fact that their primary use is NOT transportation, these fantastic feats of engineering firmly belong among the other marvels of technology in this, the technology section. So enjoy. They're not exactly cars are they...

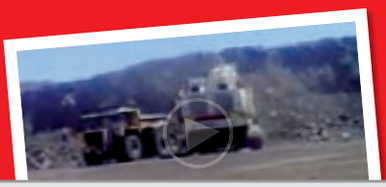
TECHNOLOGY

MASSIVE mining machines

The world is still primarily reliant on fossil fuels for energy generation. With billions of people across the globe, this means the demands that are placed on the mining industry are huge. Extracting these fossil fuels as efficiently as humanly possible is of utmost importance; and for best efficiency and ability to meet this demand, you need scale.

These five machines really are that, and much more: huge-scale engineering that you can barely get your head around. You seriously need an entirely different scale and context to get an impression of how vast these tools are – not to mention the sheer amount of fossil fuels they extract each day, around the clock.

They cost tens of millions of pounds, and last for decades, yet at their heart they remain controlled by a human being. The principals they use will be familiar to those who have driven past roadworks or looked closely at a building site. It's just that they are enlarged to dimensions to take your breath away. Read on to find out how they work.



DID YOU KNOW? *The RH400 is the world's largest hydraulic excavator*

BIGGEST DRAGLINE Bucyrus 8750

The mining industry is one that is all about scale – and when we say these machines are big, we mean BIG!

How big?!

Just in case you have trouble getting your head around just how massive this machine is...

AC ace
The AC drives in the Bucyrus are 86 per cent efficient, compared to 74 per cent efficiency for DC drives.

On the grid
Most draglines are connected direct to the electrical grid because of the sheer hunger they have for power.

Cutting-edge drive
The cutting-edge D3 direct drive technology is even more efficient, with an 89 per cent efficiency stat.

The Statistics

Bucyrus 8750

Built by: Bucyrus
Overall length: 140m
Width: 39m
Overall height: 80m

This massive dragline can clear football pitch-sized spaces right before your very eyes

The Bucyrus Dragline 8750 will run 24 hours a day, seven days a week, and excavate up to 116m³ per scoop – that's the equivalent of 58,000 two-litre water bottles. It will do this for an average of 40 years, which is why it's used in surface mining operations worldwide. There are 45 different specifications of dragline, each comes with its very own on-staff application engineer.

The 8750 series has multiple bucket capacities, and a boom length of up to 132.5m. It can reach depths of up to 79.8m. It is among the largest of all mobile equipment in the world; but when we say mobile, we do not mean fast! Moving a dragline is not the work of a moment, particularly the Bucyrus. It has a rated suspended load of up to 344,736kg and its approximate working weight is more than 7.5 tons.

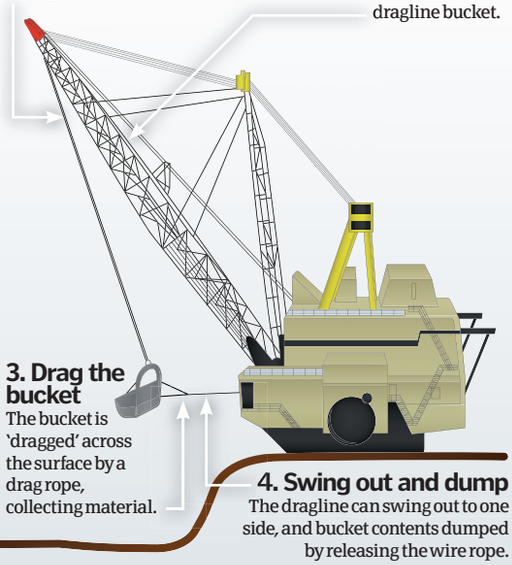
It is powered by Siemens AC drives throughout. The 8750 series comes in various guises, with the range-topper being the 8750D3. This uses gearless AC direct drive for hoist and drag – the advantages here are in efficiency. It allows fast bucket fills and the lack of hoist and drag gearing also reduces maintenance demands.

Power is provided to the AC drives by utility lines – the enormous power consumption means that connection directly to the electrical grid is often the most efficient solution.

How a dragline excavator works

1. Hoist the bucket
A bucket is suspended on a hoist coupler from the dragline's boom arm by strong hoist wires.

2. Boom arm
The hoist rope drops down from the top point of the boom arm; connected to it is the dragline bucket.



3. Drag the bucket
The bucket is 'dragged' across the surface by a drag rope, collecting material.

4. Swing out and dump
The dragline can swing out to one side, and bucket contents dumped by releasing the wire rope.

"It has up to 20 cylinders and a 95.4-litre capacity; maximum power is 4,023bhp!"

BIGGEST HAUL TRUCK
Liebherr T282C

This supertruck is the biggest of its kind in the world – a monster mining truck no mine can defeat

On-board troubleshooter
Support is available on various levels and is based around electronic communications through an online troubleshooting system.

Shifting weight distribution
When empty, the weight distribution is 54 per cent rear-biased. This changes to 67 per cent rear bias when fully laden.

Focus on service
Two service doors and better airflow to the engine and electronics mean best possible reliability and reduced servicing needs.

Brake stop unless operator says start
Electronic brakes include an anti-rollback feature – this means the ultratruck cannot move backwards on an incline unless instructed.

The Statistics

Liebherr T282C

Built by: Liebherr
Length: 15.7m
Width: 8.7m
Height: 8.3m
Weight: 266 tons
Total vehicle weight: 666 tons (fully loaded)
Payload: 400 tons

In the car world, you have supercars: but even 'supertruck' is not enough to describe this 'ultratruck' behemoth, which is used in mining operations worldwide. Its sheer scale can be judged by its empty weight of 266 tons – or more than 150 Ford Focus hatchbacks piled together. Not only that, it's also capable of carrying a 400 ton payload on top of this, giving it a weight of over 600 tons when full!

Powering it is a diesel engine that comes in either fuel-optimised or emissions-optimised setup. As with passenger cars, achieving lowest-possible exhaust emissions carries a fuel usage penalty. It has up to 20 cylinders and a 95.4-litre capacity; maximum power is 4,023bhp! The engine alone weighs 12 tons. It delivers energy to an alternator, which powers a liquid-cooled control box – this converts it into three-phase AC current.

It is moved by an AC electronic drive system called IGBT – insulated gate bipolar transistor. This uses in-wheel induction motors to move the monster truck. They allow the diesel to run independently of travel speed, therefore generating drive in the most efficient way possible. This gives better fuel economy.

The IGBT drive system can also slow the big truck down instead of using the back-up disc brakes. This regenerates electrical energy, which is used to power the truck's auxiliary systems – it is hybrid-style ecological awareness!

Road construction dumper truck drivers will find the cabin of this beast fairly familiar: it has a traditional steering wheel and pedals, and the left-hand-drive set-up includes a 12-inch colour touch screen for diagnostics. Its top speed is 40mph and the clever drive system even aids handling; in corners, drive to the outside rear wheels is increased and eased off on the inside wheels, helping it turn in better.

The T282C is constructed using a vertical integration process. On the cast truck frame sits the massive dump body, superstructure and drivetrain. Liebherr has optimised it in CAD, so reinforcements are only added in high stress areas. This has cut weight and also improved the maximum payload. The dump system is controlled using a joystick and completes a lift cycle in under 50 seconds. Fully lifted, the dump body stands nearly 50 feet high.

Multi-purpose digger
The LeTourneau can be used to load rock, coal and iron ore. It can lift up to 72,574kg.

On the fast cycle
The entire load cycle takes just 25 seconds – 16 seconds for hoist, three seconds for dump and a six-second float.

© LeTourneau

5 TOP FACTS TYPES OF MINING

1 Open cast mining
In open cast mining the minerals that lie on the surface of the earth or very near the surface are scooped and scratched out from the surface by machines like these.

2 Open-pit mining
Open-pit mining consists of recovery of materials from an open pit in the ground, quarrying or gathering building materials from an open-pit mine.

3 Strip mining
Similar in many ways to open-pit mining, this consists of stripping surface layers off to reveal the ore and seams that lie underneath.

4 Mountaintop removal
Commonly associated with coal mining, which involves taking the top of a mountain off to reach deposits at depth.

5 Sub-surface mining
Digging tunnels or shafts into the earth to reach buried ore deposits. Ore – for processing – and waste rock – for disposal – are brought to the surface through the tunnels.

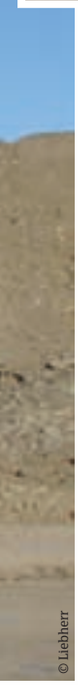
DID YOU KNOW? *The T282C has a payload of up to 400 tons*

It's murder to park but you could fit 400 tons of groceries in it

© Liebherr

Anatomy of a haul truck

Get under the hood of a Terex Titan


© Liebherr


© Alex Pang

Diesel generates electricity
A large diesel engine drives a generator, producing the electrical energy to drive the in-wheel motors. It is cooled by massive radiators.

Hydraulic ram lifter
Hydraulic rams lift the haul dump deck that has been previously loaded by another ultra-machine.

AC into forward drive
Four in-wheel motors convert AC power into forward drive, moving the haul truck at up to 40mph.

Multi-purpose wheel motors
The wheel motors also slow the haul truck – and in doing so, also regenerates electrical energy.

The Statistics

LeTourneau L-2350

Built by: LeTourneau
Length: 20.9m
Width: 7.6m
Height: 6.4m cabin height, bucket max lift 13.9m

Variety bucket
Bucket size is varied according to material density: less dense surfaces have larger buckets.

BIGGEST WHEEL LOADER
LeTourneau L-2350

These 'worker ants' are often seen on building sites – but it's not often you see one on this scale!

To clear large spaces fast, you need a LeTourneau L-2350. It's the world's biggest wheel loader, and is more than 20m long. The wheelbase alone is the length of two large executive cars, and the bucket is so big it is nearly a metre wider than the wheel loader truck itself. It is driven by a choice of several diesel engines, depending on the type of material to be excavated – it is highly flexible but used mainly in coal mining. The largest engine is 45 litres and puts out 2,300hp.

Maximum speed is 10.5mph, both forwards and backwards; an AC-DC traction drive uses four traction motors with infinitely variable speed. Braking is electronic and the L-2350 is steered by a joystick. Excavation operations use an electrohydraulic hoist and bucket; the best-match truck capacity is 400 tons and larger! As it operates in mines, all air is filtered and supplied to the engine, drive system cooling and also a pressurised cabin. Operators have a colour-coded warning light system that alerts them to engine, hydraulic, electrical and electronic problems.

The operating payload is vast, up to 72,574kg in standard form, and only slightly reduced at 68,039kg in high-light form. As standard, it has a reach of 3.18m, with the high-lift increasing this to 3.49m (and a total height of 13.89m).

"The RH400 has a bucket capacity of 50m³"

BIGGEST HYDRAULIC LOADER

Terex (now Bucyrus) RH400

Everything about the Bucyrus hydraulic excavator is huge – as you'd imagine of something that weighs nearly 1,000 tons!

In front of you is the world's largest hydraulic excavator – an $11m machine that stands a full ten metres (almost 33 feet) high and 8.6 metres wide. The record-breaking Bucyrus is used for many mining operations, including coal, copper, iron ore and oil sands; it is commonly found in Canada, but also has an underground coal mining specification.

The RH400 weighs an incredible 980 tons and is powered by two turbodiesel engines with a maximum output of 4,500bhp at 1,900rpm. Each is 60.2 litres in capacity and has 16 cylinders; they use two-stage turbocharging, aftercooling and intercooling.

The engines power hydraulic pumps, which generate very high pressure oil for driving the track motors and moving the excavator rams. There are eight main pumps and six swing pumps. Forward drive is via axial piston motors on each side; each track is two metres wide and three metres high. The total hydraulic oil volume is 13,000 litres; an electronic Pump Managing System oversees the hydraulics and incorporates flow-on-demand control.

Excavators are built of two distinct constructions – the undercarriage and the house, where the operator cab and boom reside. They fit to the undercarriage using a centre pin, meaning they can rotate 360 degrees. A torsion-resistant 9.5m-long boom and 56m-long stick provides the excavation shovelling duties; the bucket is attached on the end. The RH400 has a bucket capacity of 50m³, and various specifications are available, depending on shovelling duties: iron ore, heavy rock, oil sand and standard rock configurations are offered. Up to 3,300kN of digging force can be generated.

It achieves considerable bucket load without significant counterweights at the rear. This means it is relatively compact, which is an important consideration for use in space-restricted areas. The operator also has a comfy cabin with pneumatic seat and ergonomic joystick control system. The windscreen is armour plated and a safety switch is embedded inside the seat: when it senses it is unoccupied, all the hydraulic controls are automatically neutralised.

Low speed, high power
The maximum speed of the RH400 is 1.37mph; it can, however, generate a maximum tractive force of 4,140kN…

Eco engines
The diesel engines pass US EPA emissions laws; they are fed by a 15,100-litre diesel fuel tank.

The Statistics

Terex RH400

Built by: Bucyrus
Length: 10.98m
Width: 8.6m
Height: 9.99m

DID YOU KNOW? *A rope shovel is used for digging out surfaces such as vertical coal faces*

More of a bungalow-load than a shed-load

Comes in a range of colours including this fetching burgundy

BIGGEST ROPE SHOVEL
P&H 4100XPC

Even the largest rock faces in the world should fear this huge rope shovel

Rope shovels are the heavy duty attackers of the mining industry – and none eats away the earth faster than the P&H 4100XPC. This is the supercharged high-performance pinnacle of the rope shovel world!

A rope shovel is used for digging out surfaces such as vertical coal faces. They consist of a rotating deck where the driver cabin lies, along with the engine and a heavy counterweight. To the front of the deck a boom is attached, which carries a swing arm and a bucket.

The bucket is controlled by a series of ropes. When facing a surface to be excavated, the wire ropes are dug into the surface using a crowd arm, then pulled up through filling it with material. Once raised clear, it swings to one side and can be released into a dumper truck. P&H has cut seconds from this entire cycle with its ultra shovel. How? Through speeding up the hoist cycle by extending the shovel's speed range.

This has come at no penalty to capacity or payload, though. The nominal payload is 115 tons, and it can cut up to 16.8m high, through a radius of 23.9m. This is why the operator sits a full ten metres off the ground; the rope shovel itself is 14.7m high, and 15m long. The wire hoist rope alone is 73mm thick!

There are two hoist motors, rated at a peak 3,990hp, three swing motors, two propel motors and a single crowd motor. The operator controls it via an armrest-mounted pistol-grip joystick.

The Statistics

P&H 4100XPC

Built by: P&H
Length: 32m
Width: 14.4m
Height: 21m

Low on service
Bucyrus has fitted a xenon working light; it is ultra-bright for working around the clock; servicing is minimal and oil change intervals are 1,000 hours.

© Bucyrus International Inc.

On-board loo
The operator's cabin is so large, it can even have an optional lavatory room! There are also two work counters for appliances.

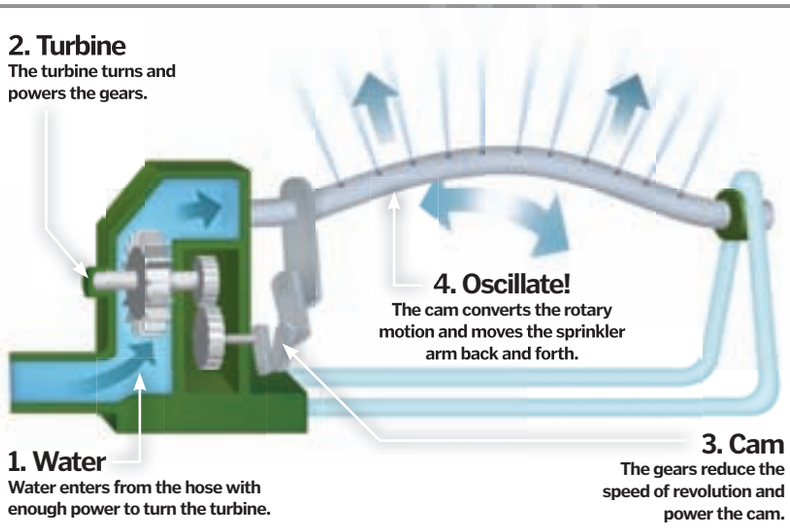
© PH Mining Equipment

Monster truck for monster shovel
P&H specifies an optimum truck size payload; this is a monumental 400 tons: even the trucks are monster trucks!

Stock the suspender
The dipper capacity is 76.5m³, and the maximum suspended load is 215 tons.

Mining Magazine
A big thanks goes to Paul Moore, Editor of Mining Magazine, for his help researching this article.
www.miningmagazine.com

DID YOU KNOW? *The first commercially sold impact sprinkler was called the 'Rain Bird'*



Sprinklers

Arguably crucial in maintaining a luscious lawn, oscillating sprinklers can offer hands-free water distribution

It's August and sprinklers on the lawn will be a common sight in yards and gardens the world over, so long as there's no hosepipe ban. The sprinkler is a simple but no-less ingenious device that harnesses the power of the water that it distributes to the lawn, and the key to its success is a turbine and a cam.

So, the sprinkler is attached to a hosepipe, the water runs through the hosepipe and is sprayed from the sprinkler arm. But how does it move back and forth? Well, as the water enters it turns a turbine, usually a cylindrical, bladed piece of plastic. The force of the water turns the turbine at a very high rate, so a system of gears are employed to slow the revolution speed.

Once slowed the rotating motion needs to be transferred to a linear one so that the arm will move back and forth. This is achieved by use of a cam which is, if you didn't know, a device that does just that. A cam can be an irregularly shaped wheel or other shape that produces a smooth reciprocating (back and forth) motion in the follower, which is a lever making contact with the cam. This back and forth motion is what causes the sprinkler arm to move and spray a fine arc of water across the surface of the lawn.

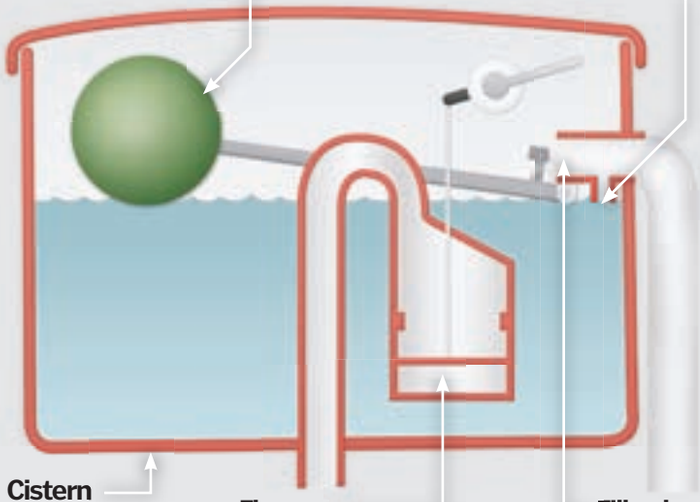
Another force called "Sod's Law" dictates that the arm will always swing towards you when you try to move the sprinkler to another part of your garden or yard...

Sprinklers can water the lawn and amuse the kids!

Ball cocks

How do they both refill and stop your toilet from overflowing?

A ball cock is a simple float valve that moderates the amount of water in your toilet's cistern. It both opens a water-in valve when the water level in your tank is low, and shuts off that valve when the water reaches a pre-set point called the toilet's fill line. A ball cock's construction is usually characterised by a hollow spherical plastic balloon on the end of a metal rod, which in turn leads to the cap of the flow valve. The plastic balloon sits on the surface of the tank's water at the fill line and when the toilet is operated and the water level in the tank reduces the balloon drops with it, lifting the valve cap in a seesaw motion. Only when the level of water in the tank is returned to the fill line does the ball cock rise to a level where the valve cap is replaced, shutting off the water supply.



"The polygraph does not detect if someone is telling a lie, just if they are exhibiting deceptive behaviour"

Traffic lights explained

From London to Shanghai, traffic lights dominate the urban landscape

Traffic lights are signalling devices used to control the flow of traffic and pedestrians. They work by presenting a colourised system that dictates an interchange's right of way, utilising a universal colour code and precise sequence. Typically traffic lights consist of a single set of colourised lights (either bulbs or LEDs) that are usually shades of red, yellow and green, running in a set cycle for a specific – albeit variable – time period, reacting when vehicle sensors – which are usually buried in the approaching carriageway – are passed over by a vehicle.

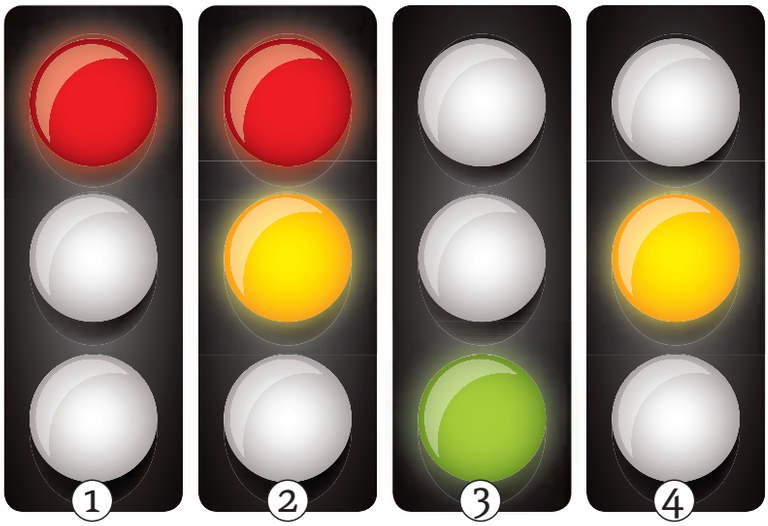
Vehicle detection occurs in three different ways. The most common is by the aforementioned buried loop sensors, which have a high sensitivity setting and easily detect large metallic objects passing over them. However, other sensors can include a movement-based system, which detects an approaching vehicle with movement sensors, and pneumatic pad systems that detect vehicles as they physically run over them.

In any of the systems mentioned the consequence of detecting the approaching traffic is simply to help dictate a traffic light's timing period and maintain an even flow of traffic in all directions.

In a standard cycle, the illumination of a traffic light's green light indicates traffic is free to proceed. When the yellow light is illuminated traffic should be prepared to stop short of the intersection if it is safe to do so, and illumination of the red light signals that traffic is prohibited from proceeding and must stop.

Any idea which one's for your lane?

UK sequence order...



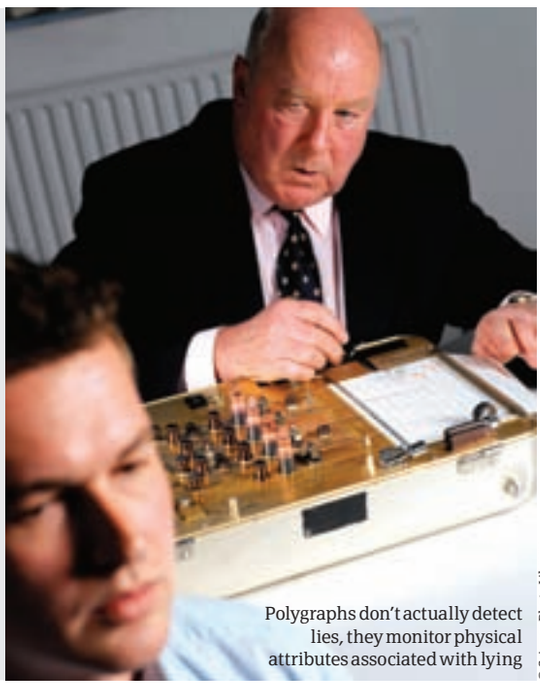
Polygraphs

How does it know if you are lying?

A polygraph works by measuring multiple physical characteristics of a person while they're asked questions to which – so the theory goes – they'll answer either truthfully or deceptively, with deceptive answers detectable by fluctuations of the aforementioned signs. The polygraph doesn't detect if someone is telling a lie, however, just if they are exhibiting deceptive behaviour.

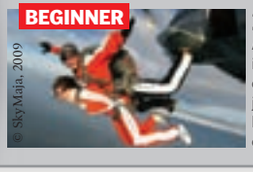
The three main physiological areas the polygraph monitors are: respiratory rate – measured by affixing two pneumographs (rubber tubes filled with air) to the test's subject's chest and abdomen; blood pressure/heart rate – measured by the traditional manner of fastening a cuff around the subject's upper arm; and galvanic skin resistance (how sweaty you are), measured by attaching fingerplates called galvanometers to the subject's fingertips.

Traditionally the information garnered from these instruments was translated and displayed on an analogue polygraph system, which consisted of a scrolling sheet of paper and a series of pen-filled mechanical arms, each attached to a set of bellows that in turn were attached to the individual instruments. So, for example, when a subject's chest muscles expanded due to heavy or fast breathing, the bellows would inflate and deflate, controlling the movement of the arm and the marks it left on the sheet of paper. Over the past 20 years, however, digital polygraph machines have become the machine of choice, utilising computer software to decode the instruments' results.



Polygraphs don't actually detect lies, they monitor physical attributes associated with lying

Head to Head PARACHUTE JUMPS



BEGINNER

1. Tandem jump
Attached to an experienced instructor, the novice can enjoy an exciting tandem jump, sitting back and letting the instructor take complete control.

INTERMEDIATE

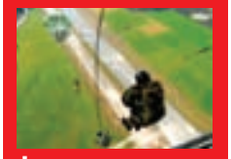
2. Formation skydiving
Formation skydiving uses aerodynamic techniques, timing and co-ordination to create spectacular aerial displays.

EXPERT

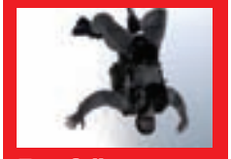
3. Wingsuit skyflying
Advanced parachutists can fly with an outfit called a wingsuit, which acts as a personal parachute shaped like an airfoil to create lift.

DID YOU KNOW? *The first successful parachute jump was completed by balloonist André Garnerin in 1797*

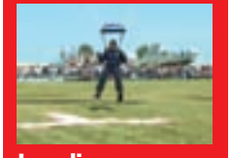
Getting down
The steps to land safely



Jump
With the need for additional oxygen, the typical altitude you would choose for your jump is 13,000 feet.



Freefall
'Freefall' begins the second you step off the plane and will last about a minute. 2,500 feet from the ground is a good time to deploy the parachute.



Landing
The ground exerts an upward force on you, stopping motion and bringing you down to Earth with a bump.

Parachutes, falling with style

Friction versus gravity in a battle to the ground

When you jump out of a plane, two major forces are competing for attention: friction (or drag) between you and the air whizzing past, and gravity pulling you down. When freefalling, you will experience acceleration because the force of friction is initially much weaker than the force of gravity. Eventually, the downward force of gravity will equal the upward force of drag and you will stop accelerating and fall at a constant speed – usually around 120mph. This is known as terminal velocity: the point at which no force is acting upon your body.

While gravity is a constant force, the force of friction changes with velocity and surface area. For example, stick your hand out the window of a stationary vehicle and you'll not experience friction. However, stick your hand out the window of a moving vehicle and you'll experience a large force of friction. Upon opening the parachute, the frictional force is greater than the force of gravity because the canopy has increased your cross-sectional area – this is what slows you down. As your acceleration drops, so too does the force of friction until it is equal to the force of gravity and again you descend at a constant rate.

Precise control

Steering a parachute is remarkably easy with the use of two handheld toggles to control the lines. The parachute canopy behaves like a wing due to the airfoil shape created by the air-filled cells. To turn left, you should pull on the left-hand toggle because this lowers the back-left section of the parachute, which also slows down that side of the 'wing'. The same goes for turning right, except that you tug on the right-hand toggle instead of the left. Pulling on both at the same time has a braking effect and will slow the whole parachute down.

"Recoil is the gun's kick-back, balancing the bullet's forward momentum"

How do semi-automatic pistols work?

The colourful profile of the semi-automatic weapon continues to shape public opinion, but there is more to its substance than style alone

The semi-automatic pistol is a functionally different animal to the romanticised revolver of the Wild West. The motivation for semi – and for that matter, full – automatics derive from energy generated by the firing process to self-load and prime a new round. This comes in a variety of flavours, including recoil, blowback and gas.

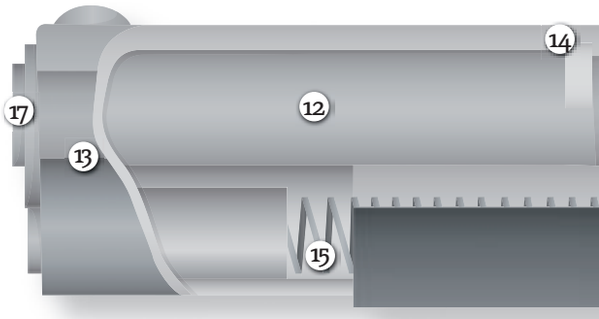
Recoil is the gun's kick-back, balancing the bullet's forward momentum – or as Newton says, with every action must come an equal and opposite reaction. Here, the opposing recoil force drives the gun backwards, initiating momentum in the 'slide' and barrel that are mechanically engaged. Separation of the two typically allows the breech to open as the slide carries on, self-loading and cocking the gun in the process.

With blowback the barrel and slide are not wed. The barrel is typically fixed to the frame with the shunting force of the exploding cartridge operating against the breech face itself and forcing the slide to the rear. The infamous AK-47 is a further example of a system that siphons gas drawn from the fired cartridge explosion to cycle the self-loading process.

Despite these distinctions, the term automatic is often clouded with reference to loading and firing. Though its function is distinct from its ancestors, the triggering mechanism of semi-automatics such as the US Army's M1911 mean they can only discharge one round for every reciprocal pull of the trigger. This differentiates them from full automatics which utilise a trigger mechanism that actuates a continuous self-loading/firing cycle until a gun's clip is spent or trigger released.

Due to the unwieldy nature of full automatic pistols, semi-automatic variants are now common throughout the military, police and criminal underworld.

Firearms training makes for better, safer shooters



Inside a semi-automatic

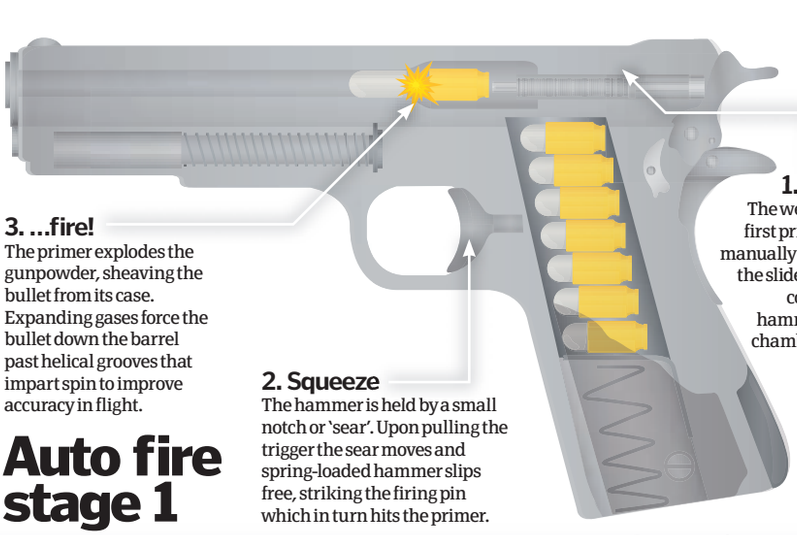
The components of the semi-automatic pistol

Pistol key:

1 Single action (SA) trigger/ double action (DA) trigger
2 Disconnector (engaged in semi-automatics)
3 Sear
4 Safety grip (must be depressed or gun will not fire)
5 Magazine/Magazine spring (holds upwards of 15 rounds or more)
6 Centerfire cartridge
7 Hammer
8 Firing pin
9 Breech
10 Extractor
11 Chamber
12 Barrel rifling
13 Slide
14 Top locking lugs
15 Recoil spring
16 Link
17 Muzzle

6. Up and out

The breech opens; the extractor and ejector take turns to draw and kick out the spent chambered cartridge. The slide continues passing over and recocking the hammer.



1. Cock

The weapon is first primed by manually racking the slide, which cocks the hammer and chambers the round.

2. Squeeze

The hammer is held by a small notch or 'sear'. Upon pulling the trigger the sear moves and spring-loaded hammer slips free, striking the firing pin which in turn hits the primer.

3. ...fire!

The primer explodes the gunpowder, sheaving the bullet from its case. Expanding gases force the bullet down the barrel past helical grooves that impart spin to improve accuracy in flight.

Auto fire stage 1

4. Shots away!

Combustion gases provide muzzle velocity upwards of 250m/s; in turn the slide recoil is locked to the barrel by 'lugs'. As the bullet exits, bore pressure falls.

5. On the slide

At this point the 'link' pivots the barrel out of lock and the lugs disengage; the slide continues to retreat under conserved momentum, compressing the recoil spring.

Auto fire stage 2

5 TOP FACTS TYPES OF GUN

1 Lever-action
Synonymous with the Winchester Rifle, this action allowed the likes of Billy the Kid to lever new rounds from a sealed tubular magazine, all in one movement.

2 Giving it both barrels
The double-barrelled shotgun is the prime example of 'break-open' in action; whereby barrels are hinged to expose the breech and ready new rounds.

3 2,000 rounds a minute
Gatling's gun housed upwards of ten barrels each with its own breech and firing pin; loaded upon cranked rotation by a gravity-fed ammunition hopper.

4 Unchained melody
The chain gun has a single barrel and employs an electric motor to drive a chain that is connected to the bolt, which moves back and forth to reload the weapon.

5 Pump up the volume!
The pump-action is most often found in repeating rifles and shotguns; with a hand grip that is pumped back and forth that strips the spent shell and loads a fresh round.

DID YOU KNOW? *Holding a full automatic on its side helps against the potential for kick up and vertical spray*

Taking cover.... along with you

Semi vs fully automatic

While both loading mechanisms are automated, the advantage of going full automatic means there is no trigger disconnect and no mechanical delay in the cycling of fire representative of semi-automatic weapons.

Therefore, while they are great in a tight spot and satisfy a penchant for wanton carnage, such continuous fire – allied to a typically low weight and no shoulder stock – makes them tough to control; and a tendency to kick-up during firing make them prone to vertical spray.

'Cook-off' is also a factor in full automatics, where a round may dispense prematurely from the over-heated chamber. Full automatics often benefit from an open bolt policy, where the slide is held back at the end of the cycle to allow cooling air to filter the barrel.

Another issue is slam fire. This occurs when the slide is released and the force of it closing is powerful enough to detonate the primer. They are also subject to jamming, where the cartridge can stick while entering, or ejecting from, the chamber.

"A trigger mechanism that actuates a continuous self-loading/ firing cycle"

The firing cycle

1. Safety first
With frame-mounted safety locking the hammer and slide allow the gun to be carried with hammer in a "cocked and locked" state.

2. Reconnecting the disconnect
Linked to the trigger, this acts as a second sear, which catches the hammer or striker if the trigger is held. The disconnector is active until the trigger is released, and the hammer falls back on the regular sear.

3. The round house
The magazine is a distinct separation from classic cylindrical multi-chambered revolvers, housing upwards of 15 rounds or more. Note the chambered centerfire round: unlike rimfire, whose primer is built into the rim of the base; therefore when struck the case is not deformed and can be re-used.

4. Closed-bolt design
Commonly seen in semi-automatics that are less prone to 'cook-off', but also found on full automatics. Once cocked, the slide is forward and breech closed, with the chamber housing a fully loaded round.

5. First shot accuracy
The single-action trigger (unlike double-action) doesn't cock the hammer, so requiring a shallow press; minimising mechanical disturbance and enhancing the aim.

7. Relock...
The slide is propelled forward by the unwinding recoil spring; the returning breech closes and the slide locks into place with the barrel.

8. ...and reload
The slide returns over the hammer (now cocked) and strips a round from the magazine, which is then thrust forward into the chamber.

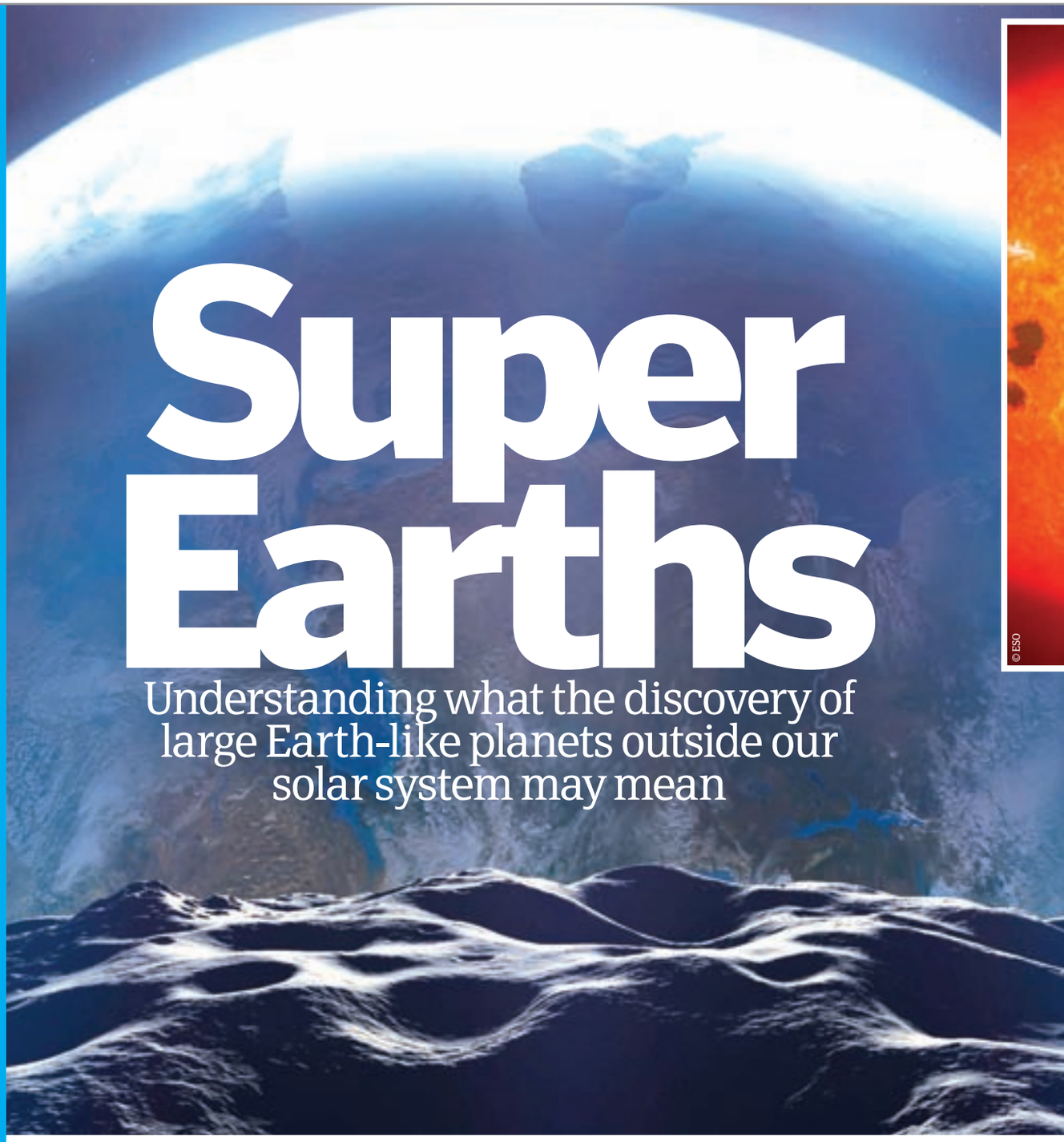
9. Trigger happy
In a full automatic the disconnector is not engaged in events. Therefore, keeping the trigger pulled results in a continuous cycling of fire until it's released or all ammo is spent.

Auto fire stage 3

This month in **Space**

The search for exoplanets was covered a couple of issues ago and touched on the subject of Super Earths, massive terrestrial planets that orbit stars in other solar systems. We thought these so fascinating that they merited a closer look and you can find out more about these huge Earth-like interstellar bodies on this very page. Another highlight this month is the IKAROS, an amazing solar-powered space yacht from the Japanese Space Agency.

SPACE



Super Earths

Understanding what the discovery of large Earth-like planets outside our solar system may mean

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In 1992, radio astronomers Dale Frail and Aleksander Wolszczan announced that they had discovered two (later confirmed to be three) planets orbiting the pulsar PSR B1257+12, located approximately 900 light years from the Sun. These planets were the first to be discovered outside of our solar system. They were also the first to be discovered orbiting a pulsar instead of a regular, or main-sequence star, something astronomers hadn't previously known was even possible. These planets were later classified as Super Earths – extrasolar planets with masses somewhere between those of Earth's and those of gas giant planets such as Jupiter.

Astronomers differ on exactly what makes one of these exoplanets a Super Earth, because it's a concept that is so new that it's still evolving. There's not yet a formal definition. For some, the classification is purely based on the planet's mass and has nothing to do with its atmosphere, surface or other characteristics. That might make the term "Super Earth" seem a bit misleading, because not all of these planets are very Earth-like – some of them are gaseous planets that are too small to be classified as gas giants.

Most astronomers do agree that Super Earths have a mass up to ten times greater than that of Earth's, but whether that includes planets with masses less than five times greater than that of Earth's depends on who you choose to ask. To further compound the issue, astronomers are generally only able to estimate a minimum mass for the planet. The lower the exoplanet's mass, however,

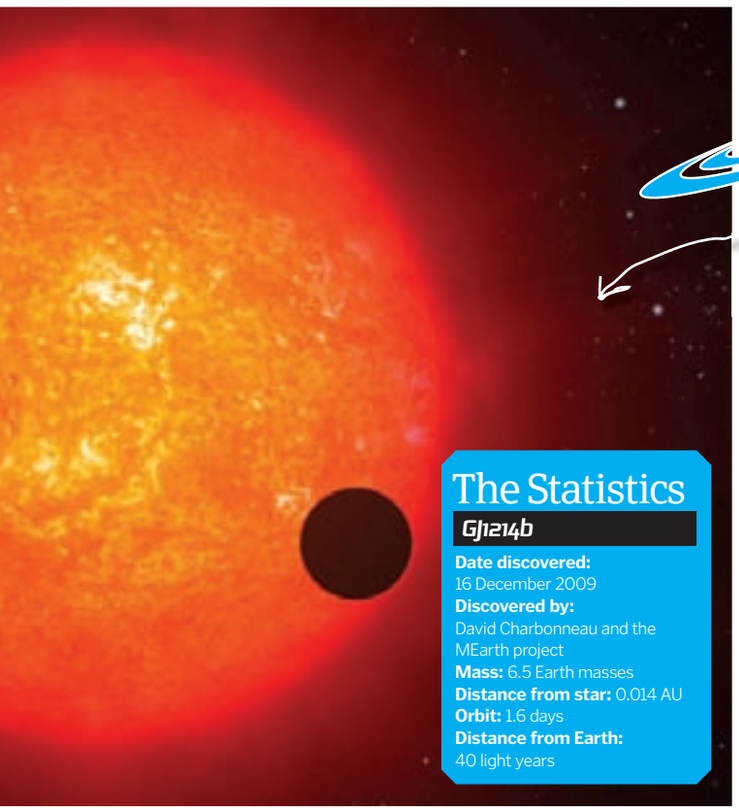
Head to Head SUPER EARTHS

1. Gliese 876d
This Super Earth has a mass of about 7.5 times that of Earth. Discovered in 2005, it is probably a terrestrial planet and lies 15 light years away.

2. HD 40307d
Discovered back in 2008 using the HARPS apparatus, this possible gas exoplanet is estimated to have a mass 9.4 times that of Earth's.

3. HD 69830 b
This exoplanet, discovered in 2006 in the Puppis constellation, is likely to be rocky. Its mass is at the upper limit at ten times that of Earth's.

DID YOU KNOW? *NASA's Kepler Mission and the joint CNES/ESA COROT satellite are dedicated to searching for Earth-like planets*



class: NEAREST

GJ1214b

GJ1214b is a unique Super Earth because it is relatively close to Earth – about 40 light years away. It was discovered by a project funded by the United States National Science Foundation called MEarth, which uses ground-based telescopes described as being very similar to those of amateur astronomers. The finding was confirmed by the HARPS spectrograph. GJ1214b is located in the Ophiuchus constellation and probably has a watery surface. Its extremely high surface temperature, estimated at about 2,700°C, makes it too hot to support life.

The Statistics
GJ1214b

Date discovered: 16 December 2009
Discovered by: David Charbonneau and the MEarth project
Mass: 6.5 Earth masses
Distance from star: 0.014 AU
Orbit: 1.6 days
Distance from Earth: 40 light years

class: FIRST FOUND

The Statistics
PSR B1257+12b

Date discovered: 1992
Discovered by: Dale Frail and Aleksander Wolszczan
Mass: 4.3 Earth masses (not yet confirmed)
Distance from star: 0.36 AU
Orbit: 66.5 days
Distance from Earth: 900 light years

One of three

The first Super Earth was one of three discovered about the same time, found to be orbiting the pulsar PSR B1257+12. Using the Aricebo radio telescope in Puerto Rico, astronomers Dale Frail and Aleksander Wolszczan noticed that the pulsar had irregularities in its pulses. Further investigation showed that planets were the cause. B1257+12b and its companion Super Earths are believed to be terrestrial planets that possibly formed after a supernova. They could also be the rocky cores of gas giants that had their atmospheres stripped away due to close proximity to the pulsar.

the more likely it is to be terrestrial and therefore potentially habitable. Because of this, some astronomers believe that the term "Super Earth" should only actually be used for planets that are terrestrial.

In order for a Super Earth to be habitable, it has to meet lots of criteria. One important factor is whether the planet is in a system that has what astronomers call the habitable zone. This is an area where an Earth-like planet can have liquid water on the surface. If the planet is too far from the star, any water on its surface will freeze. If it's too close, the water will simply boil away. Some Super Earths that have been discovered are thought to be icy, while others are more rocky and Earth-like. However, even icy Super Earths could support life via colonisation if the atmosphere were otherwise suitable.

In some cases, Super Earth means more than just a greater mass than Earth; it means greater surface temperatures than Earth's, for example. This could mean that a Super Earth would be able to harbour life for longer than Earth. One model shows that life could survive on a Super Earth for about 3 billion years longer than life is estimated to survive on Earth. Characteristics such as volcanism keep the atmosphere full of carbon dioxide, helping to continue the essential process of photosynthesis.

So far, the Super Earth with the most potential is Gliese 876d. It is also the first Super Earth discovered to be orbiting around a main sequence star. Discovered in 2005 and about 15 light years away, it is estimated to have a minimum mass of 7.5 times that of Earth's mass. Further studies have shown that Gliese 876d is in its star's habitable zone and could have large oceans on its surface. Although it likely only gets about 30 per cent of the sunlight that the Earth does, astronomers believe that it could have atmospheric gases in enough abundance to produce a significant greenhouse effect. This would result in surface temperatures high enough to support life. In comparison, without its greenhouse gases, Earth's temperature would be around –19°C.

Most Super Earths – and there have been around 30 discovered ▶

class: FARTHEST

The Statistics
OGLE-2005-BLG-390Lb

Date discovered: 25 January 2006
Discovered by: PLANET/Robonet, OGLE, MOA
Mass: 5 Earth masses
Distance from star: 2-4.1 AU
Orbit: 10 years
Distance from Earth: 21,000 light years

OGLE-2005-BLG-390Lb

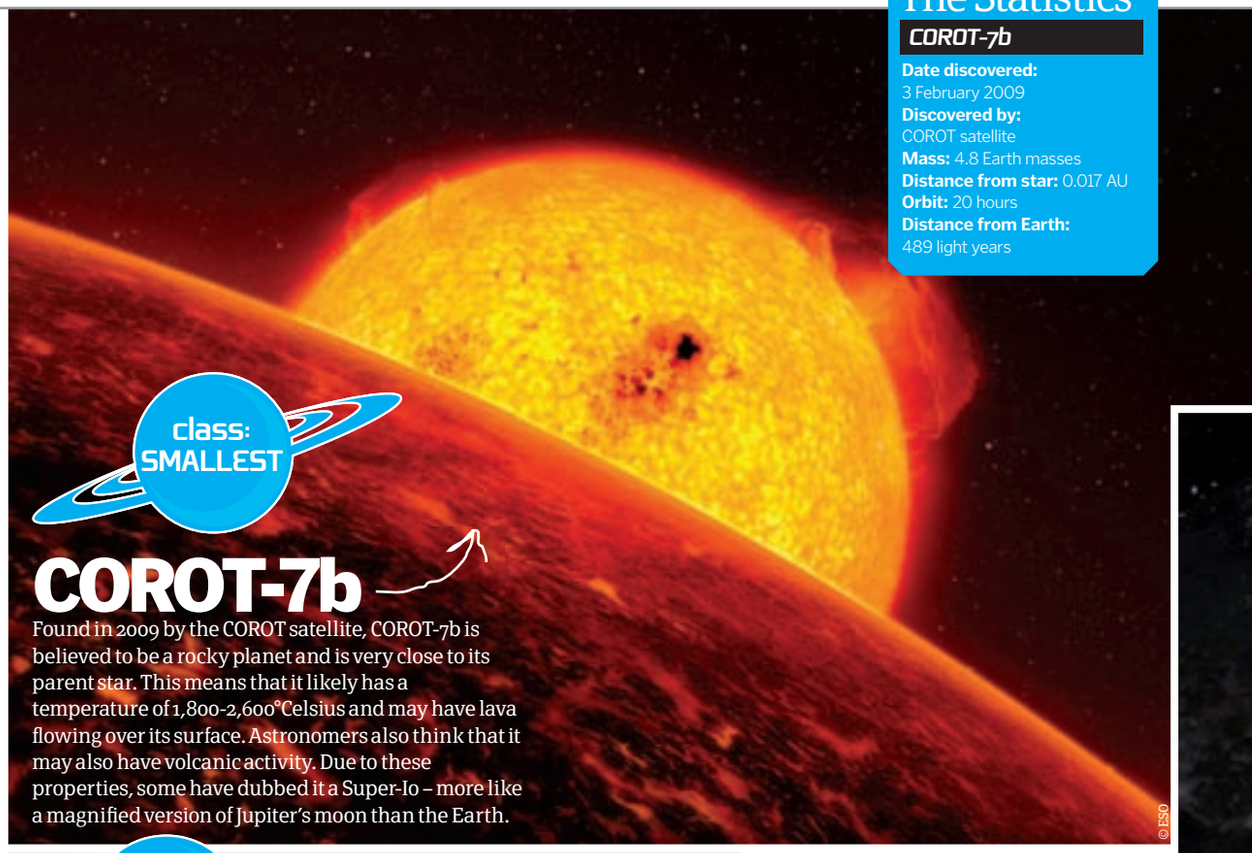
This Super Earth discovery was announced jointly on 26 January 2006 by the Probing Lensing Anomalies NETwork/Robotic Telescope Network, the Optical Gravitational Lensing Experiment and the Microlensing Observations in Astrophysics. It is about 21,000 light years away from Earth and about five times Earth's mass with a potentially rocky core. The Super Earth is fairly distant from its parent star, and that star is likely a cool red dwarf with a relatively low temperature. Because of this, astronomers do not believe that OGLE-2005-BLG-390Lb is likely to be able to support life.

"Icy Super Earths could support life via colonisation"

as of January 2010 – have been found through the use of a high-precision spectrograph, which measures light properties in part of the electromagnetic spectrum. One of these spectrographs is the High Accuracy Radial Velocity Planet Searcher (HARPS). This instrument is attached to a 3.6-metre telescope at the La Silla Observatory in Chile operated by the European Southern Observatory. HARPS detects planets by the radial velocity method, also known as the Doppler or "wobbly" method. This involves finding changes in the velocity of stars as they react to the gravity of planets located around them. It is so precise that it can detect velocity changes as slow as 3.5 kilometres per hour.

The radial velocity method has been a very productive way to detect Super Earths, and it gives astronomers an idea about its minimum mass as well as its orbit. When used in conjunction with other methods, astronomers can infer more about these exoplanets. The transit method, which measures the reduction of light in a star as its planets pass by it, can tell us about a Super Earth's possible temperature, atmosphere, composition and surface gravity. Gas planets and rocky planets look differently when they pass in front of their parent star. When a rocky planet transits, its star dims quickly due to its thin atmosphere. A gradual dimming occurs when a gas planet passes, as the light is filtered through the many atmospheric layers. Analysing the light can also tell astronomers more about the composition of the atmosphere as well as its surface.

Studying Super Earths can tell us more about what's happening outside of our solar system. We can also learn more about the relationships between planets and stars, and learn more about how planets form and evolve. What makes many people excited, however, is the potential for existing life on these planets or the potential for our colonisation. A planet with a mass greater than Earth's, however, is going to be quite different from Earth. This doesn't mean that a Super Earth will be bigger than Earth in terms of diameter. In fact, it's more likely to be smaller. Super Earths are also more likely to have higher temperatures, a denser atmosphere, a greater gravitational pull, and more active plate tectonics. However, these factors don't automatically rule out a Super Earth as potentially habitable. There's still a lot to learn about the Super Earths that we've already discovered, and more are being discovered all the time.



The Statistics

COROT-7b

Date discovered: 3 February 2009
Discovered by: COROT satellite
Mass: 4.8 Earth masses
Distance from star: 0.017 AU
Orbit: 20 hours
Distance from Earth: 489 light years

class: SMALLEST

COROT-7b

Found in 2009 by the COROT satellite, COROT-7b is believed to be a rocky planet and is very close to its parent star. This means that it likely has a temperature of 1,800-2,600°Celsius and may have lava flowing over its surface. Astronomers also think that it may also have volcanic activity. Due to these properties, some have dubbed it a Super-Io – more like a magnified version of Jupiter's moon than the Earth.

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class: LARGEST

HD 69830 b

Although it's massive for a Super Earth, HD 69830 b is actually the least-massive planet in its system. Some have called it a Neptune-mass planet rather than a Super Earth, but it is believed to have a rocky core similar to that of Earth's. Some astronomers predict that if HD 69830 b is a rocky planet, tidal heating would result in massive temperature fluctuations on its surface.

The Statistics

HD 69830 b

Date discovered: 2006
Discovered by: HARPS
Mass: 10 Earth masses
Distance from star: 0.785 AU
Orbit: 8.667 days
Distance from Earth: 41 light years

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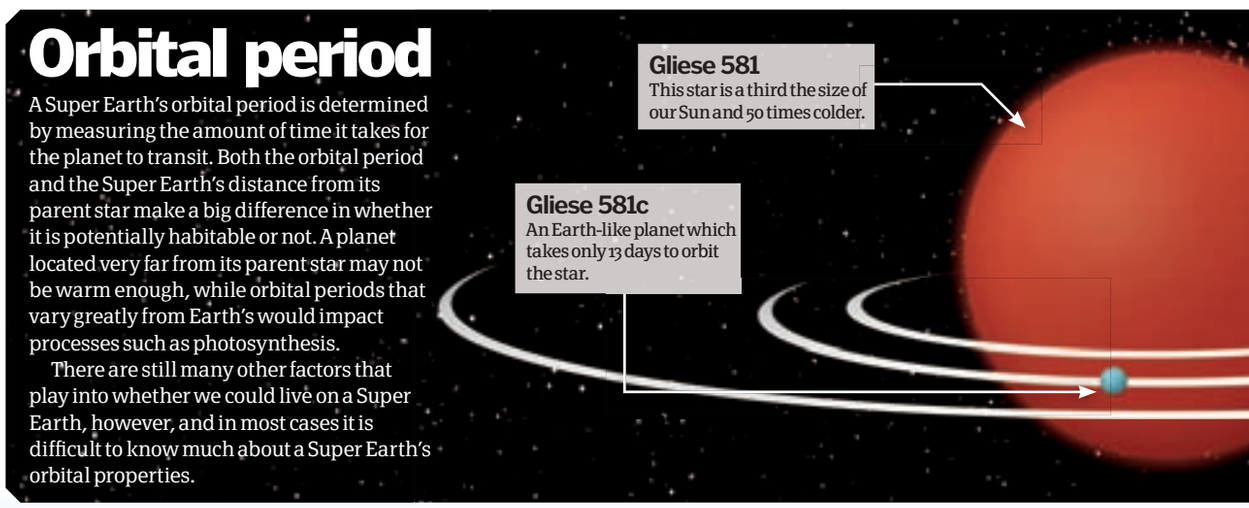
© NASA

Orbital period

A Super Earth's orbital period is determined by measuring the amount of time it takes for the planet to transit. Both the orbital period and the Super Earth's distance from its parent star make a big difference in whether it is potentially habitable or not. A planet located very far from its parent star may not be warm enough, while orbital periods that vary greatly from Earth's would impact processes such as photosynthesis.

There are still many other factors that play into whether we could live on a Super Earth, however, and in most cases it is difficult to know much about a Super Earth's orbital properties.



5 TOP FACTS SUPER EARTHS

Prove it
1 Astronomers have believed in the existence of Super Earths since the early 19th Century, but had no way to prove it until more powerful instrumentation was invented.

Massive planets
2 After Earth, the next most-massive planet in our own solar system is the gas giant Uranus, with a mass more than 14 times that of Earth's.

Goldilocks Zone
3 Extrasolar planets that are thought to be very Earth-like and "just right" for habitation are sometimes called Goldilocks planets, after the children's story.

Odds in our favour
4 Terrestrial Super Earths are being discovered in greater and greater numbers, raising the likelihood that we will eventually find a habitable Super Earth.

Planet killers
5 Some astronomers believe that Uranus and Neptune may have "swallowed" embryonic Super Earths in our own solar system approximately 4 billion years ago.

DID YOU KNOW? *Without its greenhouse gases, Earth's temperature would be around -19°C*

HD 156668b

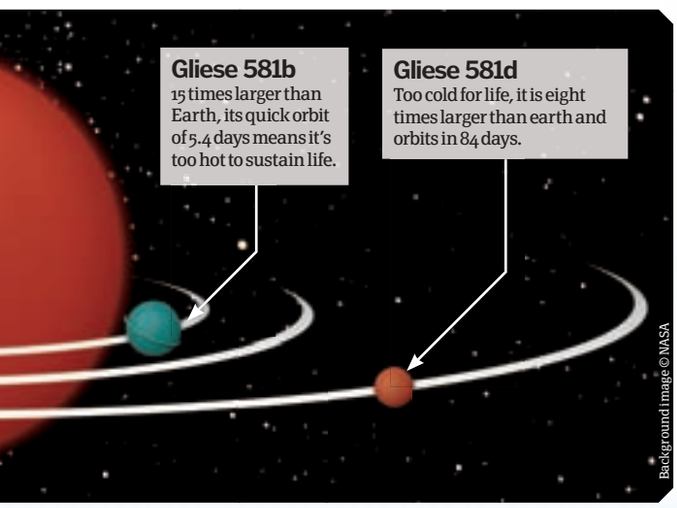
class: MOST RECENT

The most recent Super Earth discovered is also the next-to-smallest Super Earth to be uncovered so far. A team of astronomers known as the California Planet Research Team announced that they had found the exoplanet via the radial velocity method in January 2010. The team observed HD 156668b at the Keck Observatory in Hawaii through the ten-metre Keck Telescope, which contains a high-resolution spectrograph. The Super Earth is located in the Hercules constellation, which is also home to a number of other exoplanets.

The Statistics

HD 156668b

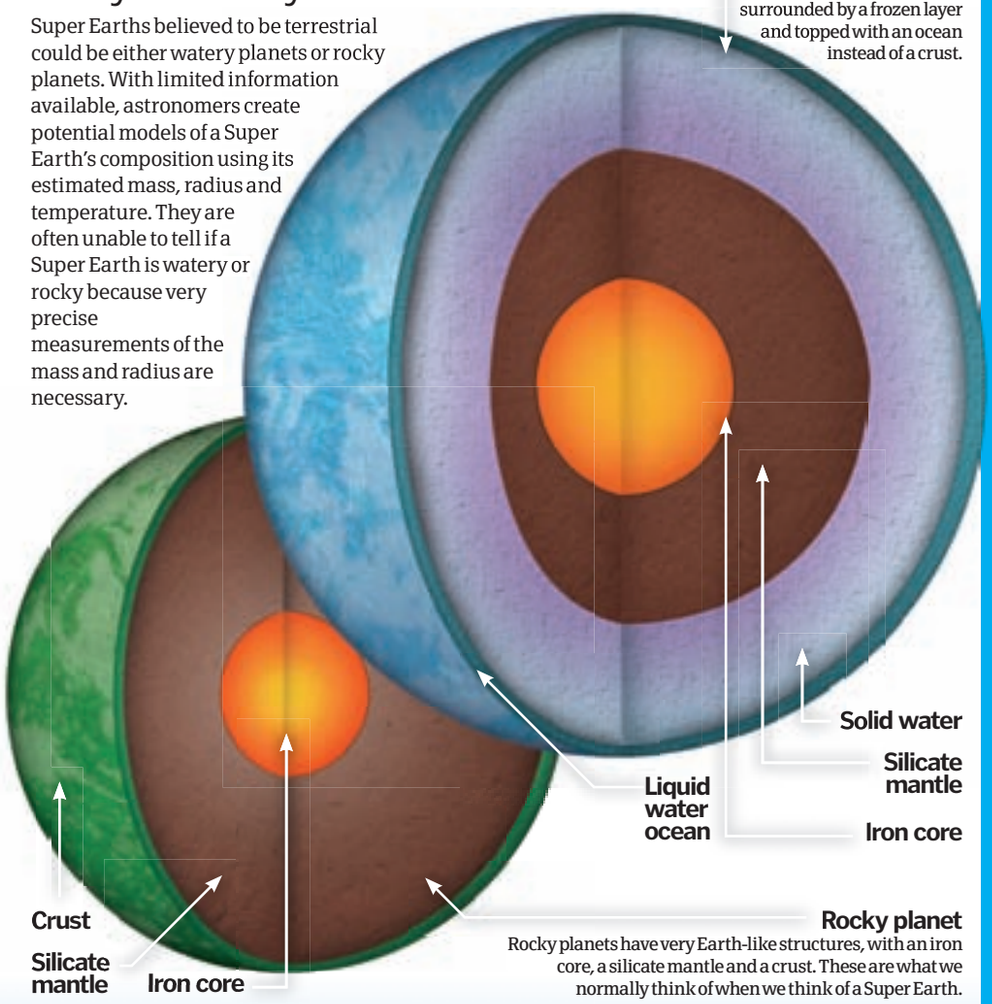
Date discovered: 7 January 2010
Discovered by: California Planet Research Team led by Andrew Howard
Mass: 3.1 Earth masses
Distance from star: 0.05 AU
Orbit: 4.646 days
Distance from Earth: 80 light years



Super Earth anatomy

Using mass, radius and temperature to discover if a Super Earth is rocky or watery

Super Earths believed to be terrestrial could be either watery planets or rocky planets. With limited information available, astronomers create potential models of a Super Earth's composition using its estimated mass, radius and temperature. They are often unable to tell if a Super Earth is watery or rocky because very precise measurements of the mass and radius are necessary.



"Meteorites originate from the asteroid belt"


© NASA


The Earth is bombarded with meteors every day
© NASA

Shooting stars

The eye-catching space invaders that can have a deadly impact

Meteors are not literally shooting or falling stars. In reality, the majority are caused by dust debris from passing comets. This debris can be as small as a grain of sand, which enters our atmosphere at a speed of 71 kilometres a second. The rapid compression of air in front of the meteor creates a high temperature that causes it to glow and produce a trail of gases. Pebble-sized meteors can be seen burning up through the action of atmospheric ram pressure at an altitude of 120 kilometres.

At certain times of year, Earth enters a swarm of debris that causes meteor showers that radiate from specific constellations. Peaking around 17 November, showers appear from Leo and are named Leonids.

Thousands of meteors hit our atmosphere every day, which are completely destroyed or reduced to dust particles. Large meteors that reach the Earth's surface are called meteorites. Annually, approximately 500 meteorites – ranging from 40 centimetres up to 20 metres in size – arrive here, and every million years or so you can expect a two-kilometre monster. Meteorites tend to originate from the asteroid belt, and are composed of stone (aerolites) or iron (siderites).

Finding meteorites

Up to the 20th Century, the majority of meteorites recovered were composed of iron, mainly because they stood out from local rocks. To discover more types of meteorite, Harvey Nininger started searching the cultivated Great Plains of the USA, where there are few natural rocks. This resulted in the recovery of 200 stone-type meteorites.

Remote areas of Earth such as the ice fields of Antarctica and the deserts of Australia, southwest USA, north Africa, and southwest Asia have yielded thousands more meteorites.

The Arecibo Observatory

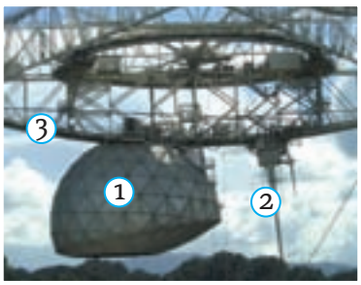
The world's largest single dish radio telescope

The Arecibo radio telescope is located near the equator in Puerto Rico, where it officially opened in 1963. The dish listens-in to naturally occurring radio emissions from distant galaxies, and it can study nearby planets and comets by bouncing signals off them.

Concrete towers
18 steel cables radiate from the towers to suspend the platform above the dish.

Height adjustment
Three pairs of cables attached to concrete blocks and giant jacks underneath the dish run to each corner of the platform. This enables the height of the platform to be adjusted to the nearest millimetre.

Platform
Based on a bridge-like design, it weighs 900 tons and is suspended 138 metres above the dish. It carries and accurately positions the Gregorian dome and radio antennas.



Platform receiver

1. Gregorian dome
This houses both the secondary and tertiary reflectors. The signals from outer space reflect off the dish to the secondary dish inside the dome, and on to the tertiary dish. The signal is then fed to a control room where it is amplified and processed by the scientists and experts.

2. Carriage house
Specially designed linear antennas point down from here. They are individually tuned to many different narrow frequencies.

3. Azimuth arm
The dome and carriage house can run along this 93-metre long curved arm, up to 20 degrees from the vertical. It is attached to a circular track, enabling the arm to be rotated 360 degrees. The mechanism works to a tolerance of a millimetre.

Reflecting dish
The spherical reflector has a diameter of 305 metres, a curvature of 265 metres and reaches a depth of 57 metres. Radio emissions are reflected from the dish to the Gregorian dome and the carriage house antennas, which are suspended over it.

THE STATS THE MOON

AVERAGE DISTANCE FROM EARTH 384,400km

PERIGEE (CLOSEST TO EARTH) **363,300km**

APOGEE (FARTHEST FROM EARTH) **405,500km**

EQUATORIAL RADIUS 1,737.4km

DID YOU KNOW? *In ancient times, it was wrongly believed that the moon was magnified by atmospheric phenomena*

The Moon Illusion

Why does the moon appear so unfeasibly large near the horizon?

Now, this one's trickier than it sounds. We've all seen how a rising or setting moon on the horizon appears larger than an overhead moon, and yet scientists and psychologists still can't agree on or understand why it occurs – even NASA can't fathom it.

There are two main theories behind what's been dubbed the 'Moon Illusion'. We know the size of the moon doesn't actually change so we can safely assume that it's a trick of the mind. One idea suggests the viewer instinctively attempts to judge the distance to the rising moon (it's hard to comprehend 400,000km) based on visual objects, such as trees and houses in the distance. These objects seem near the moon, giving a distorted point of reference, making it appear bigger. However, this theory can be called into question as pilots have also seen the illusion despite no point of reference against the ground.

The second theory has to do with the fact that we tend to think of the sky as a flattened dome, rather than the hemisphere it is, and therefore perceive things overhead (birds and planes) as much lower, or nearer than the things we see on the horizon. And so although the moon may well be the same size whether it's above your head or off on the horizon, because you believe it is farther away at the horizon you perceive the moon to be much larger. Either way, your brain has been tricked.

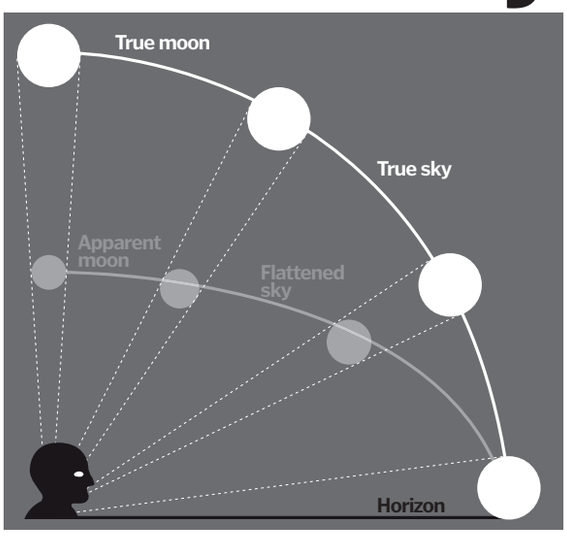
Close enough to touch? Not quite...

The Ponzo track

The theory that the objects in the foreground affect how far away we believe the moon to be can be comprehended by looking at Mario Ponzo's railway track diagram in which two physically identical lines appear different sizes due to the perspective created by the tracks converging in the distance. The line at the top of the diagram appears wider than the line below because it seems to span a greater distance across the railway lines, which we wrongly perceive as parallel. We're also reminded of the *Father Ted* episode when Ted explains to Dougal that the toys cows are 'small' but the real cows outside are 'far away'.

The flattened sky

The idea that we perceive the moon differently because we've come to mentally imagine the sky around us as a flattened dome, instead of the true half sphere that it is, can be seen here. Although you can clearly see in the diagram that the actual distance between the viewer and the moon doesn't change, our brain's perception of the extra distance to the moon is compensated for by showing us an apparently enlarged moon at the horizon.



How do you weigh planets?

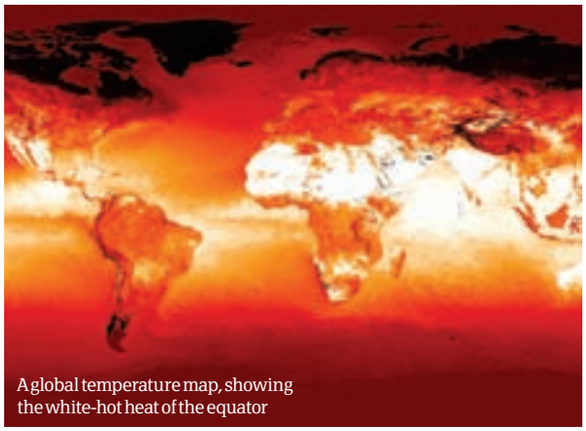
It seems like an impossible task, but how can scientists use an orbiting moon to work out the weight of a planet?

Newton's Law of Gravitation states that every planetary body has its own gravitational field that pulls on nearby objects – such as moons or spacecraft – with a force proportional to its mass and inversely proportional to the square of the distance between the two objects. Newton also discovered that an object – a moon, for instance – will move at a constant speed and in a straight line unless acted upon by a force such as gravity that will keep the moon in orbit.

By observing the effect of a planet's gravitational attraction on an orbiting moon, scientists can measure the planet's mass. The gravitational attraction between the moon and the planet depends on their mass and the distance between their centres. The heavier the planet, the stronger its attraction to the moon and the faster the moon will travel. Measuring the distance from the planet to the moon and calculating how long it takes to orbit enables astronomers to calculate the weight of a planet.

How hot is it on other worlds?

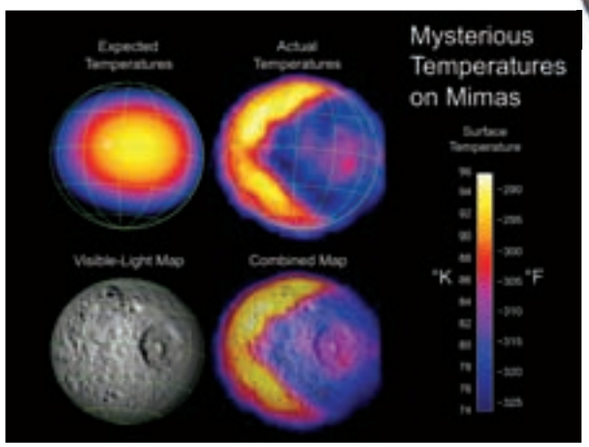
How infrared telescopes enable us to 'see' the temperatures of planets



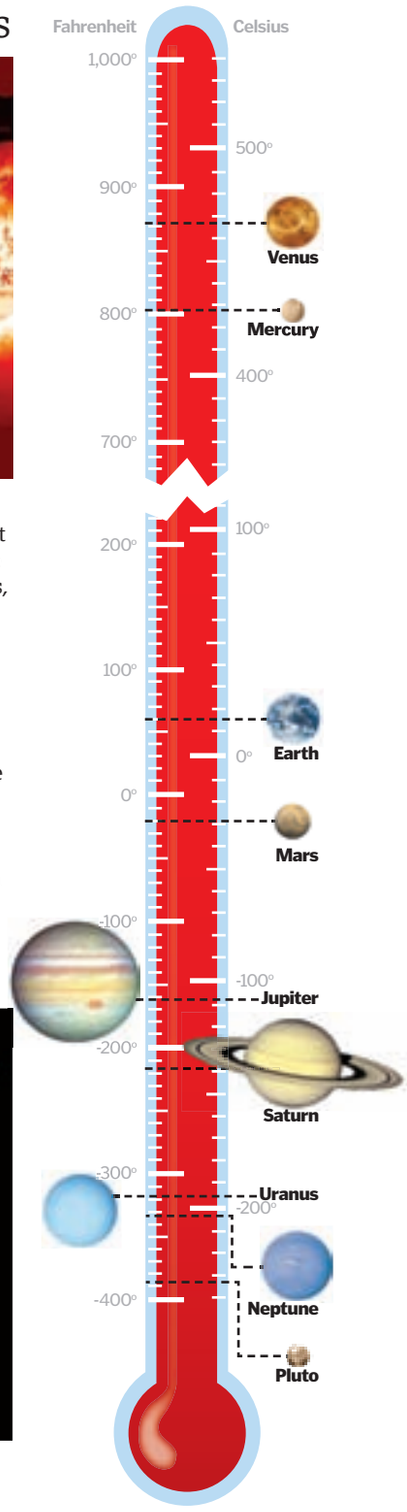
A global temperature map, showing the white-hot heat of the equator

Heat energy is emitted by all objects, including planets. The hotter the planet, the more radiation it gives off. Objects in space emit radiation across the electromagnetic (EM) spectrum – really hot objects, like stars and galaxies for instance, emit much of their energy in the visible, ultraviolet and x-ray range of the EM spectrum. However, celestial objects – such as planets and moons in particular – emit (or glow with) infrared radiation, which is outside the visible wavelength range. This means we cannot see this infrared light with our own eyes; we can only detect the visible light coming from the object. However, just because infrared rays are invisible, it doesn't mean they're not there.

Astronomers have put devices – such as the Spitzer Space Telescope – into orbit that collect and focus the infrared information from distant planets and display it as light we can see. The hotter the planet, the brighter the infrared light information it will produce. If you could see in infrared you would be able to 'see' variations in temperature across the surface of a planet.



The infrared information of Saturn's moon Mimas here was collected by a composite infrared spectrometer (CIRS) on the Cassini spacecraft on 13 February 2010



THE STATS ODYSSEY

LAUNCH VEHICLE Delta II 7925 | LAUNCH DATE 07/04/01 | TYPE Mars orbiter
WEIGHT 730kg | POWER 750 watts | COST $297 million

DID YOU KNOW? *The Odyssey was named in honour of Arthur C Clarke's 2001: A Space Odyssey*

The 2001 Mars Odyssey

The first spacecraft to report the existence of water on Mars

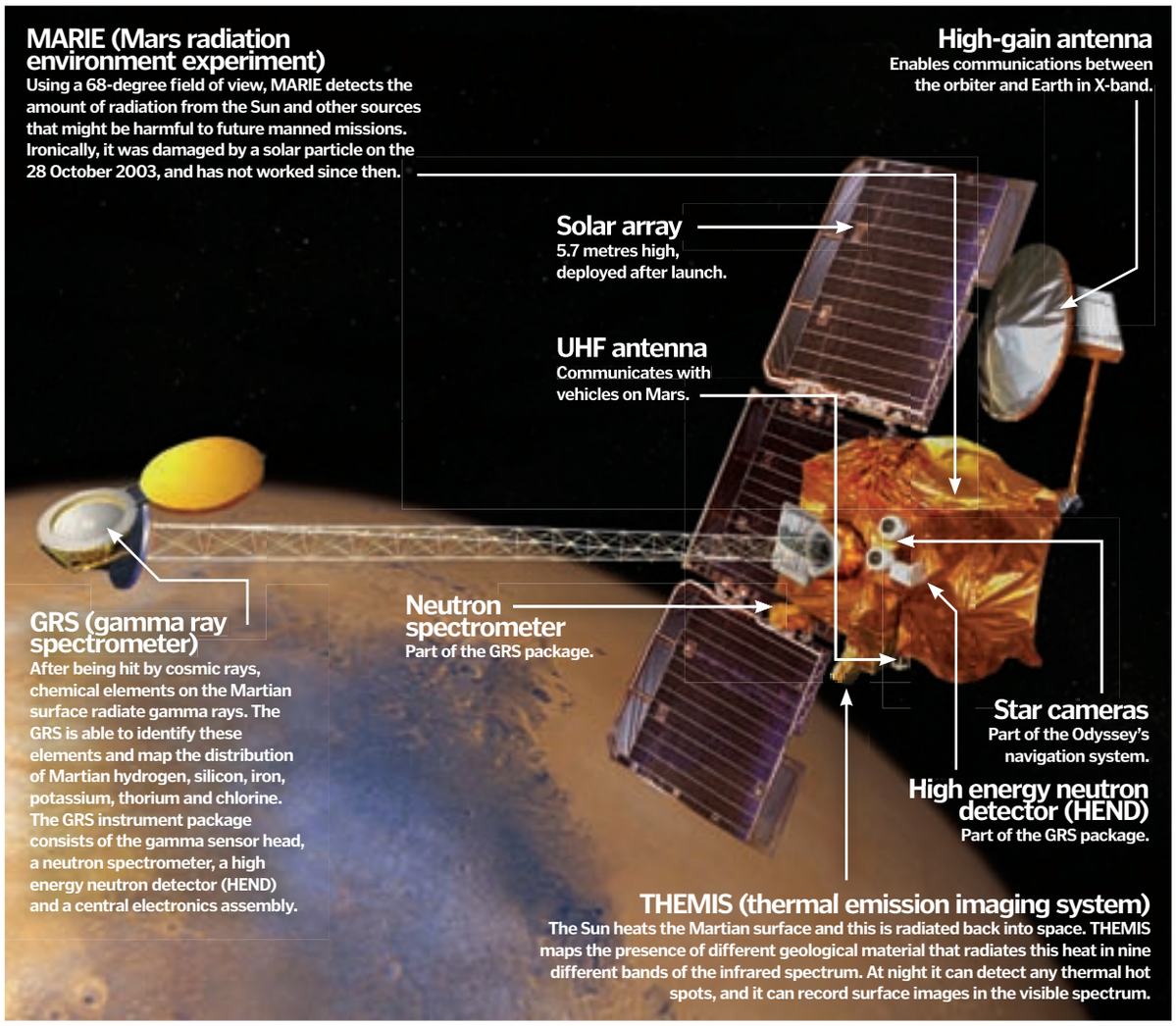
The box-like body of the Odyssey is constructed of aluminium and tough, yet very light, titanium. It features one main engine that put it into the orbit of Mars, and four small thruster engines that correct its attitude and trajectory when necessary.

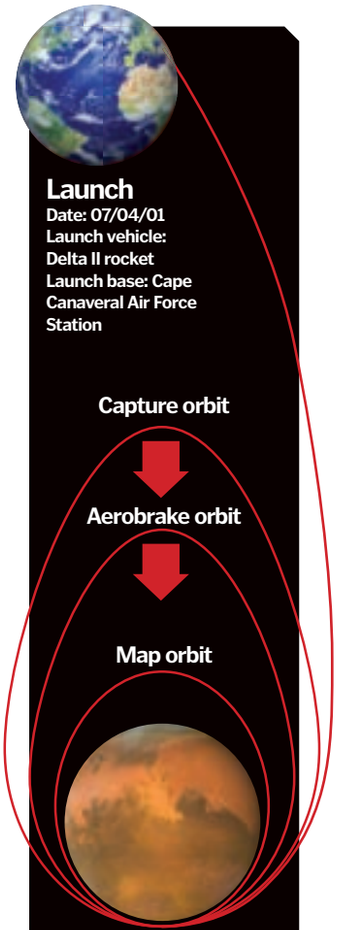
It guided itself all the way to Mars using a star camera to check its position in relation to the star field. This information was checked with an inertial measurement unit, which recorded the craft's orientation, and it used a camera that detected the position of the Sun.

Arriving at Mars, Odyssey used a technique called aerobraking to obtain a circular orbit, 400 kilometres above Mars. This used the atmosphere of the planet to slow it down, and saved having to carry a large fuel load. This phase of the mission ran from 23 October 2001 until 11 January 2002.

A RAD6000 computer that is protected from radiation and based on PowerPC chips used in Macintosh computers controls the craft. It only has 128 megabytes of random access memory (RAM) and three megabytes of memory in the case of a power cut.

Communications between the Odyssey and Earth is conducted using an X-band microwave system, while an ultra-high frequency system is used to communicate with the craft on Mars.





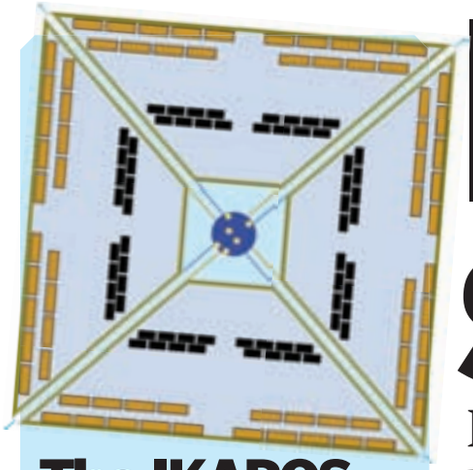
Mission

The 2001 Mars Odyssey craft is part of NASA's long-term project to explore Mars, look for evidence of life and find landing sites for future missions. Its mapping of the mineral and chemical elements of Mars, from February 2002 to August 2004, revealed huge amounts of water ice beneath the surface of the polar regions.

Odyssey is also used to relay communications from the Mars Exploration Rovers, Spirit and Opportunity, and the Phoenix Lander craft, back to Earth.

Odyssey's mission continues until 2015, you can follow its progress at the 2001 Mars Odyssey website http://mars.jpl.nasa.gov/odyssey.

"The challenge will be keeping the solar sail flat"



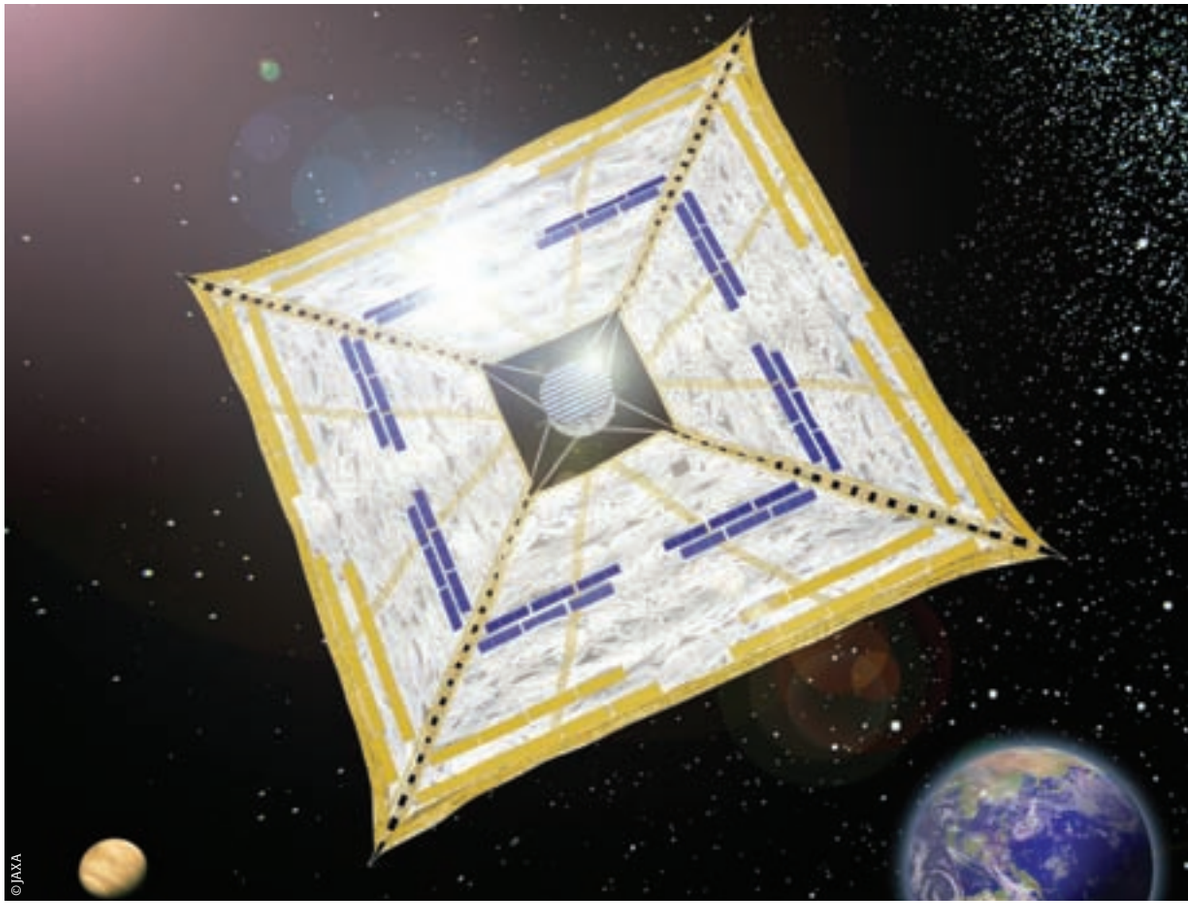
IKAROS solar sail

IKAROS is the first space mission to be propelled by sunlight alone

On 21 May 2010, the Japan Aerospace Exploration Agency (JAXA) launched a new kind of spacecraft. Named IKAROS, short for Interplanetary Kite-craft Accelerated by Radiation of the Sun, this square-shaped craft is propelled through space by using the Sun's energy in two different ways. It is embedded with thin solar cells that store sunlight as electricity, and it also reflects light particles from the Sun. As the light particles bounce off the sail, they should provide the bulk of the momentum needed to propel the craft.

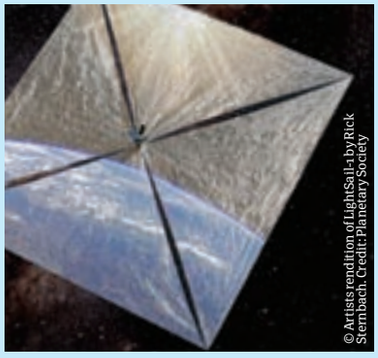
IKAROS was launched on an H-IIA rocket from the Tanegashima Space Center on Tanegashima Island in Japan. The rocket also carried an unmanned Venus probe called Akatsuki and some small satellites. IKAROS will take the same trajectory as Akatsuki, but will pass by Venus and keep going on its way to the Sun.

The solar sail weighs about 315 kilograms in total and cost around £11 million to build and launch. A previous Japanese space organisation, the Institute of Space and Astronautical Science, demonstrated successful deployment of prototype solar sails in 2004, but the propulsion system remains unproven. However, JAXA is confident that IKAROS will reach its ultimate destination. The challenge will be keeping the solar sail flat, stable and orientated correctly to take in enough sunlight.



The IKAROS membrane

The sail is made of four trapezoid-shaped panels of polyimide, a lightweight material about 32 micrometres thick. It is about 20 metres on the diagonal. One side of the sail has an aluminium layer, which reflects sunlight and provides thrust. The sail is embedded with several different components. Silicon solar cells about 25 micrometres thick are attached at points around the centre perimeter of the sail. LCD panels are also arrayed around the sail, which are used to control its attitude, or steer. Dust collectors will take samples of the debris encountered by the sail and relay it to a dust counter on the main body.



IKAROS's competition

An independent non-profit organisation called the Planetary Society has had its own solar sail project in the works. LightSail-1 is based on the NanoSail-D, a former NASA project. The Planetary Society hopes to launch LightSail-1 by the end of 2010, but the launch is dependent on funding and whether rockets are available. The membranes will be made of Mylar and its body will comprise several tiny satellites called CubeSats.

5 TOP FACTS JAXA PROJECTS

Hayabusa
1 Hayabusa was a probe sent to gather samples from asteroid 25143 Itokawa. After numerous glitches, the probe returned to Earth; scientists have not yet opened the sample container.

SELENE
2 The largest lunar mission since NASA's Apollo, SELENE orbited the moon for 20 months. It provided data used to improve topographical and gravity maps.

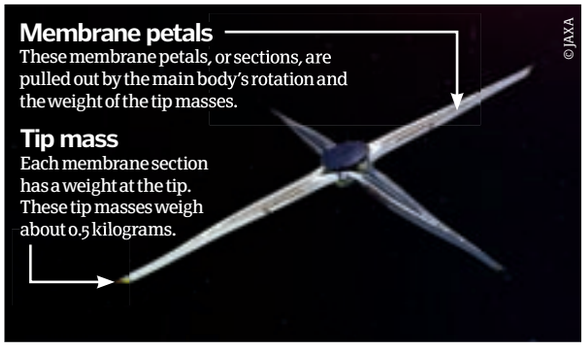
Akari
3 In 2006, JAXA launched Akari, an infrared astronomy satellite. Its mission is to survey the entire sky in infrared. On 26 August 2007 it had surveyed 94 per cent.

OICETS
4 This experimental satellite was designed to demonstrate optical communications between distant satellites. Launched in 2005, it was retired in 2009.

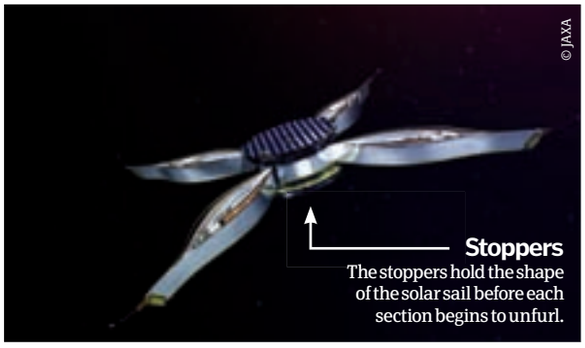
Yohkoh
5 Launched in 1991, Yohkoh orbited the Sun for over a decade. It made observations via x-ray telescope and provided insight into the behaviour of the Sun's corona.

DID YOU KNOW? *The name is similar to Icarus, a figure in Greek mythology who melted his wings flying too close to the Sun*

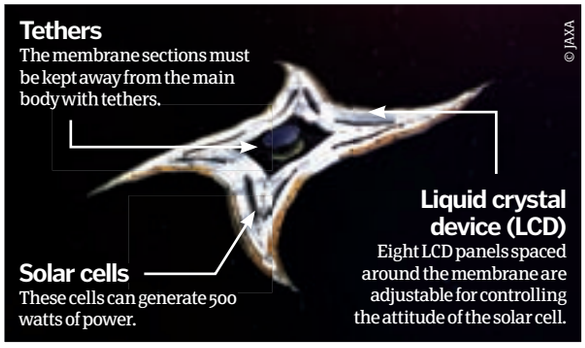
IKAROS deployment



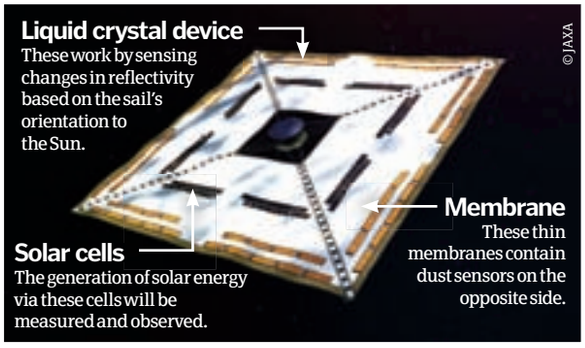
FIRST STAGE: In this first stage of deployment, actuators in the main body release tip masses. As the sail continues to rotate, the membrane petals emerge and form a cross shape about two and a half minutes after the initial launch.



SECOND STAGE: Next, the motor drivers turn to orient stoppers into alignment, and spring hinges release the stoppers to maintain tension and keep the shape of the solar sail. The membrane sections begin to unfurl.



THIRD STAGE: The solar sail continues to spin at 25rpm as each membrane section is deployed. The rotation helps to keep the membranes flat.

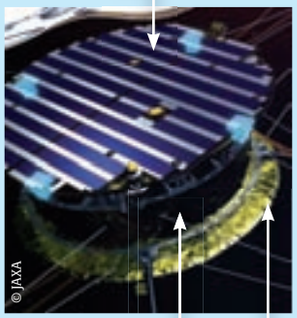


DEPLOYMENT COMPLETION: With the membranes fully deployed, the sail spins down to just a few rpms. The sail should now begin generating enough solar power to accelerate.

Central hub

This image focuses on the central hub, or main body of the solar sail. Upon separating from the H-IIA launch rocket, the main body began to spin at about 5rpms, facing the Sun. As it continued on its trajectory, the hub reached 20rpms and communicated with mission control.

Upper deck
The upper deck of the main body contains instrumentation such as the low- and high-gain antennas for communication via X-band and a dust counter.



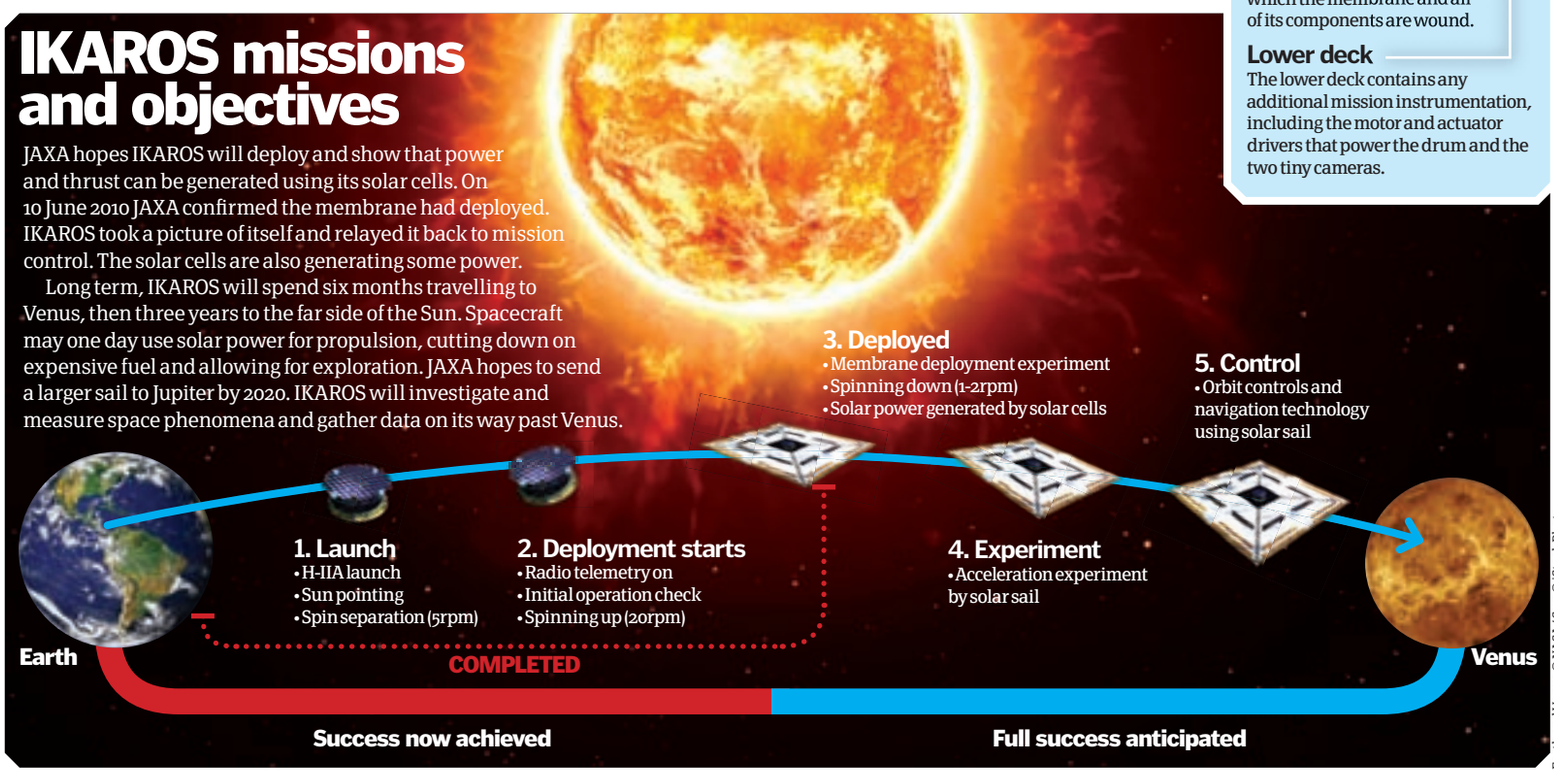
Middle deck
This centre component consists of a drum around which the membrane and all of its components are wound.

Lower deck
The lower deck contains any additional mission instrumentation, including the motor and actuator drivers that power the drum and the two tiny cameras.

IKAROS missions and objectives

JAXA hopes IKAROS will deploy and show that power and thrust can be generated using its solar cells. On 10 June 2010 JAXA confirmed the membrane had deployed. IKAROS took a picture of itself and relayed it back to mission control. The solar cells are also generating some power.

Long term, IKAROS will spend six months travelling to Venus, then three years to the far side of the Sun. Spacecraft may one day use solar power for propulsion, cutting down on expensive fuel and allowing for exploration. JAXA hopes to send a larger sail to Jupiter by 2020. IKAROS will investigate and measure space phenomena and gather data on its way past Venus.



Earth and Venus © NASA / Sun © iStock Photo

"With the arrival of the New Horizons spacecraft in 2015 we should know more about this very distant body"

Pluto

The elusive Planet X that became an ex-planet and still has many X factors

The astronomer Percival Lowell predicted the existence of a ninth planet in our solar system, beyond the orbit of Neptune. Lowell failed to find Planet X in his lifetime, but Clyde Tombaugh – using the Lowell Observatory in Arizona – confirmed his calculations. Shortly after Planet X's discovery back in January 1930 it was named Pluto. In 1978, however, it was determined that Lowell's theory based on the mass of Pluto and its effects on Uranus and Neptune were incorrect. Tombaugh's discovery was just a very lucky coincidence.

Pluto takes a leisurely 248 years to orbit the Sun. Its highly elliptical orbit takes it to a maximum of 7.4 billion kilometres from the sun (at aphelion, or farthest from the Sun) to as close as 4.5 billion kilometres (at perihelion, or closest to the Sun). Twice in this orbit it is actually closer to the Sun than Neptune, as was the case from January 1979 to February 1999.

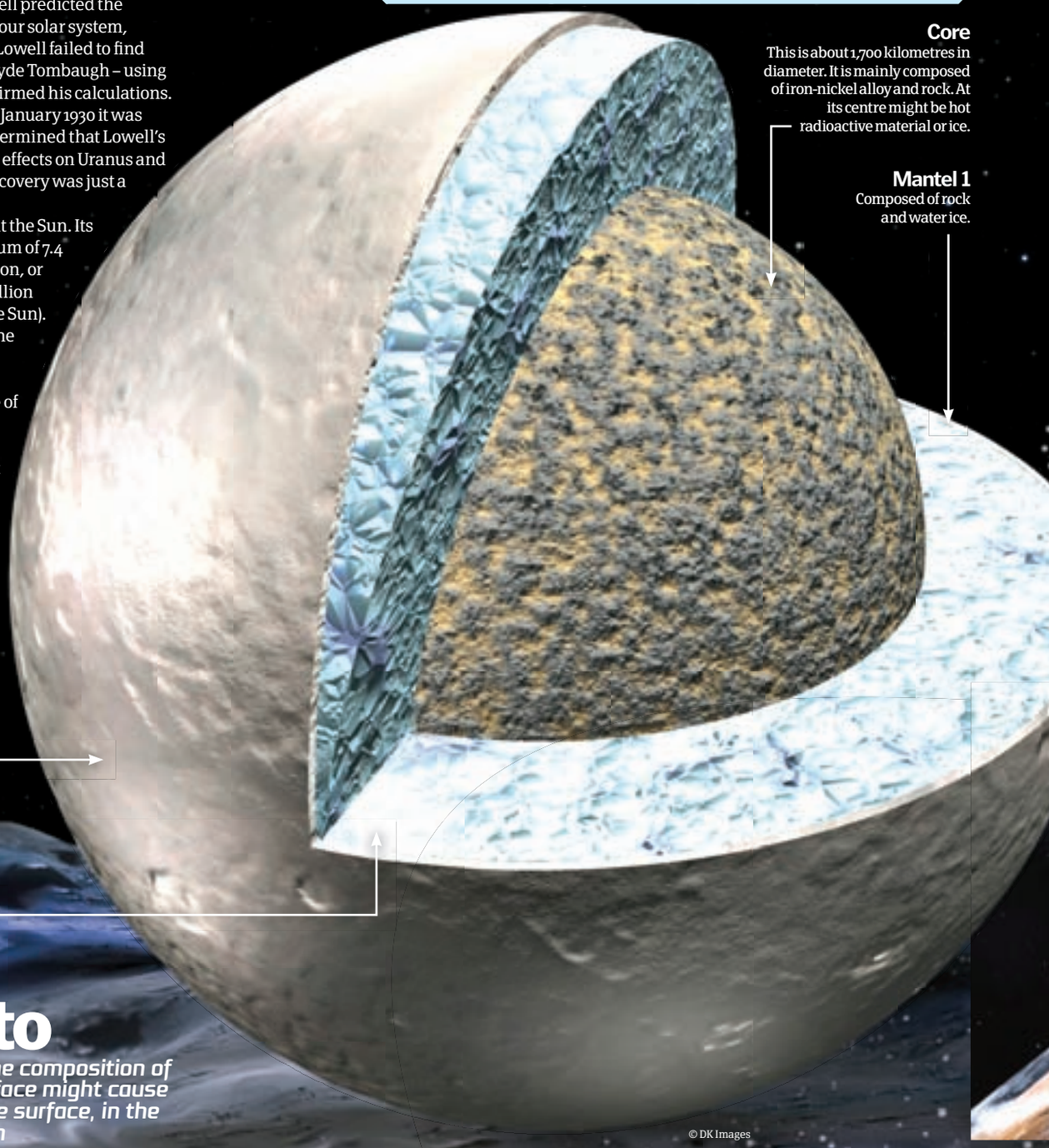
All the other planets orbit on the plane of the ecliptic, but Pluto's orbit is at an inclination of 17 degrees to this plane. Pluto is also unusual because it rotates at an angle of 122 degrees to its own axis, in a clockwise direction. This retrograde motion means it is spinning in an opposite direction to its counter-clockwise orbit around the Sun.

So far, even the Hubble Space Telescope has only obtained grainy pictures of its surface, and it is not until the arrival of the New Horizons spacecraft in 2015 that we should know more about this small, distant and very cold body.

Surface details

Using observations by the Hubble Space Telescope, and maps produced since the Eighties, it has been found that the surface of Pluto undergoes many large variations in brightness and colour.

From 1994 to 2003, the southern hemisphere darkened, while the northern hemisphere got brighter. It has a slightly less red colour than Mars, with an orange cast similar to Jupiter's moon Io. It got redder from 2000 to 2002, and other colour variations of dark orange, charcoal black and white have been observed. These seasonal variations are regarded as being due to the orbital eccentricity and axial tilt of Pluto that are reflecting topographic features and the flux of the frozen surface of the planet with its rarefied atmosphere.



Inside Pluto

So far, we know little about the composition of Pluto. Ice beneath Pluto's surface might cause movement and changes on the surface, in the same way glaciers do on Earth

5 TOP FACTS PLUTO

Finding Pluto
1 Clyde Tombaugh systematically photographed the sky and checked 1.5 million stars recorded by his photographic plates before he found Pluto.

Naming Pluto
2 Venetia Burney, an 11-year-old schoolgirl in Oxford, put forward the name Pluto. She picked it after the Roman god of the underworld. Her reward was a £5 note.

Nix and Hydra
3 The Hubble Space Telescope discovered these moons of Pluto in 2005. Nix orbits Pluto at a distance of 48,000 kilometres and Hydra, 65,000 kilometres.

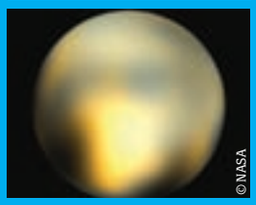
Kuiper Belt
4 Pluto is part of a cluster of Kuiper Belt Objects (KBOs) that orbit beyond Neptune. It consists of icy and rocky objects that failed to form into planets.

Triton
5 It was thought that Pluto was a satellite of Neptune. This is no longer regarded as possible, but Pluto does have many characteristics similar to Neptune's moon, Triton.

DID YOU KNOW? *Out of 1,000 names suggested for Planet X, three were shortlisted: Minerva, Cronus and Pluto*

The Statistics

134340 Pluto



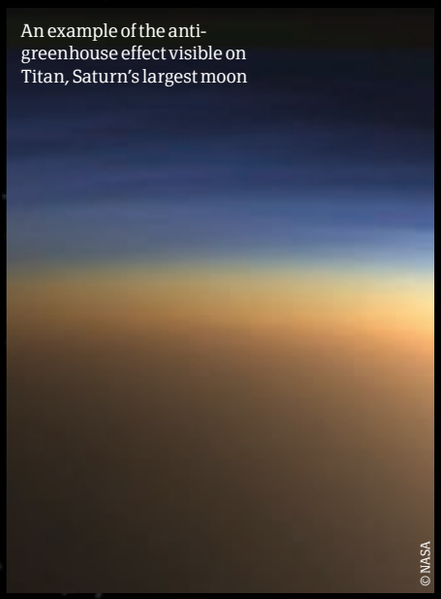
Diameter: 2,320 kilometres
Mass: 1.3 x 10^{22} kilograms
Density: 2 grams per cubic centimetre
Average surface temperature: -230˚C or -382˚F (44K)
Core temperature: Unknown
Average distance from the Sun: 5,913,520,000 kilometres (39.5 AU)
Surface gravity: 0.067g
Moons: 3

Atmosphere

When Pluto's elongated orbit takes it relatively close to the Sun, the frozen nitrogen, methane and carbon monoxide on its surface sublimates into a tenuous gaseous form. This creates winds and clouds, but the weak gravitational force of Pluto means that it can escape into space and interact with its moon, Charon.

In the process of sublimation an anti-greenhouse effect is created, which lowers the temperature of Pluto to -230°C against the expected -220°C, which is the temperature of Charon. In the lower atmosphere, a concentration of methane creates a temperature inversion that makes the upper atmosphere warmer by three to 15 degrees every kilometre upwards. On average, the upper atmosphere is 50°C warmer than the surface of Pluto.

When Pluto's orbit takes it away from the Sun, the gaseous atmosphere freezes and falls to the surface.



An example of the anti-greenhouse effect visible on Titan, Saturn's largest moon

Charon

Pluto's closest moon is Charon, which was discovered in 1978. It is 19,640 kilometres from Pluto, so from Earth they look like one planet. Charon has the same 6.4 day rate of rotation as Pluto so they always present the same face to each other. On Pluto, the surface facing Charon has more methane ice than the opposite face, which has more carbon monoxide and nitrogen ice.

Charon has a diameter of 1,210 kilometres, and has a grey surface with a bluer hue than Pluto. This indicates the surface could be covered in water ice rather than nitrogen ice. It is also speculated that methane has leaked from the grasp of its weak gravity to Pluto.

An artist's impression of the New Horizons craft

Sizes
Earth diameter: 8,000 miles
Pluto diameter: 1,400 miles

What is a planet?

Pluto's status as a planet was safe until the Nineties. This was when huge 'hot Jupiter' extra-solar planets were discovered, and objects were observed beyond the orbit of Neptune that rivalled the size of Pluto. Faced with the dilemma of defining a planet the International Astronomical Union (IAU) decided that it must be spherical, that it orbits the Sun and is clear of any planetary neighbours. Consequently, the IAU reclassified Pluto as a dwarf planet on the 24 August 2006.

An image of Pluto, with Charon visible to the bottom-left

Plutoids

Plutoids, as defined by the IAU, are dwarf planets that orbit the Sun beyond Neptune, are round, have not cleared the neighbourhood of other similar bodies, and are not satellites of another planetary body. There could be at least 70 trans-Neptunian objects (TNOs) that might be plutoids.

So far only a few have been found and named. Besides Pluto, Makemake, Haumea and Eris have been classified as plutoids. Mike Brown and his Caltech team at the Palomar Observatory discovered them all in 2005. Eris is virtually the same size as Pluto and might have been regarded as a planet before the new classification system came into effect.

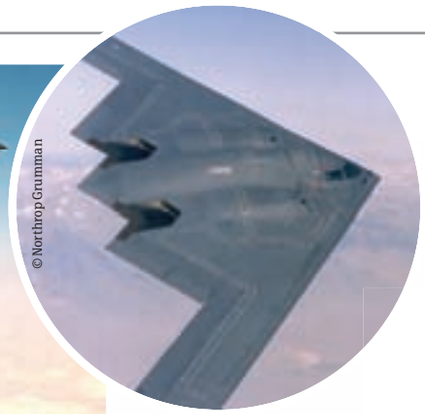
© NASA

This month in **Transport**

Often forgotten as a part of the emergency services, the RNLI and its lifeguards have saved over 139,000 lives since 1824. An impressive feat considering that it's funded by charitable donations and staffed mostly by volunteers. Our main transport feature takes a look at the boats and technology that help make daring rescues at sea.

TRANSPORT

You may not see the plane, but you'll see the bombs



Composite materials
Any radar returns are reduced by the composite materials used, which further deflect any signals.

Crew compartment
The B-2 carries two crew, a pilot and a mission commander with room for a third if needed.

Fly-by-wire
The B-2's unique shape makes it unstable, and it relies on a computer to stabilise it and keep it flying.

Windows
The B-2's windows have a fine wire mesh built into them, designed to scatter radar.

Air Intakes
To further reduce the B2's signature, the engine intakes are sunk into the main body

Stealth Bomber

The B-2 is extraordinary, both in terms of appearance and design

The 'flying wing' shaped Stealth Bomber is a unique aircraft that's designed to make it as invisible as possible. Its shape means there are very few leading edges for radar to reflect from, reducing its signature dramatically. This is further enhanced by the composite materials from which the aircraft is constructed and the coatings on its surface. These are so successful that despite having a 172-foot wingspan, the B-2's radar signature is an astounding 0.1m².

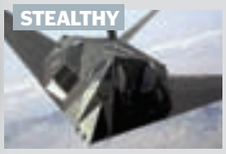
The B-2's stealth capabilities, and aerodynamic shape, are further enhanced by the fact its engines are buried inside the wing. This means the induction fans at the front of the engines are concealed while the engine exhaust is minimised. As a result, the B-2's thermal signature is kept to the bare minimum, making it harder for thermal sensors to detect the bomber as well as lowering the aircraft's acoustic footprint.

The design also means the B-2 is both highly aerodynamic and fuel efficient. The B-2's maximum range is 6,000 nautical miles and as a result the aircraft has often been used for long-range missions, some lasting 30 hours and in one case, 50. The B-2 is so highly automated that it's possible for a single crew member to fly while the other sleeps, uses the lavatory or prepares a hot meal and this combination of range and versatility has meant the aircraft has been used to research sleep cycles to improve crew performance on long-range missions.

Despite this, the aircraft's success comes with a hefty price tag. Each B-2 costs $737 million and must be kept in a climate-controlled hangar to make sure the stealth materials remain intact. These problems aside though, the Spirit is an astonishing aircraft, even if, chances are, you won't see one unless the pilots want you to...

Not one you're likely to find in your I-Spy book...

Head to Head STEALTH AIRCRAFT



1. F-117 Nighthawk
The original stealth fighter's odd, angular design reflects radar signals away from itself. It was retired in 2008.

2. Lockheed Martin F-35 Lightning II
The F-35 is designed to minimise its radar signature, including hexagonal weapon and landing bay doors that don't return as strong a signal.

3. F-22 Raptor
The F-22 Raptor carries an on-board computer that warns of any wear and tear that could possibly make the aircraft more visible on radar.

DID YOU KNOW? *The earliest example of the 'flying wing' design dated from German designer Hugo Junkers in 1919*

Ghost works: Inside the Spirit

The B-2 is an unusual combination of complexity and elegance, the entire airframe built around the concept of stealth and focused on making the aircraft as hard to detect as possible.

Flying wing
The B-2's shape means it has very few leading edges, making it harder to detect on radar.

Carbon-reinforced plastic
Special heat-resistant material near the exhausts mean the airframe absorbs very little heat.

Bomb rack assembly (BRA)
The bomb rack assembly can hold up to 80 500lb bombs.

Engines
The B-2's four General Electric F118s don't have afterburners as the heat these generate would make the aircraft easier to detect.

Rotary launch assembly (RLA)
The RLA allows the B-2 to deploy different weapons in quick succession.

Landing gear doors
The landing gear doors are hexagonal to further break up the B-2's radar profile.

The Statistics

B-2 Spirit

Manufacturer: Northrop Grumman
Year deployed: 1993
Dimensions: Length: 69ft, wingspan: 172ft, height: 17ft
Weight empty / max: 158,000lb / 336,500lb
Unit cost: $737,000,000
Max speed: Mach 0.95 (604mph)
Propulsion: General Electric F118-GE-100 non-afterburning turbofans
Ceiling: 50,000ft
Armament description: The B-2 has two internal bays capable of holding 50,000lb of ordnance. Common payloads include:
- 80 × 500lb class bombs (Mk-82) mounted on the bomb rack assembly or BRA
- 36 × 750lb CBU class bombs on BRA
- 16 × 2,000lb class weapons (Mk-84, JDAM-84, JDAM-102) mounted on the rotary launcher assembly RLA
- 16 × B61 or B83 nuclear weapons on the RLA

Landings are fine, if the tower spots you coming...

The B-2's engines are buried within the wing

"Electronics are increasingly found in 4x4 systems, but the basic engineering remains the same"

Four-wheel drive

How does this technology allow you to keep on moving over all terrain in all weather conditions?

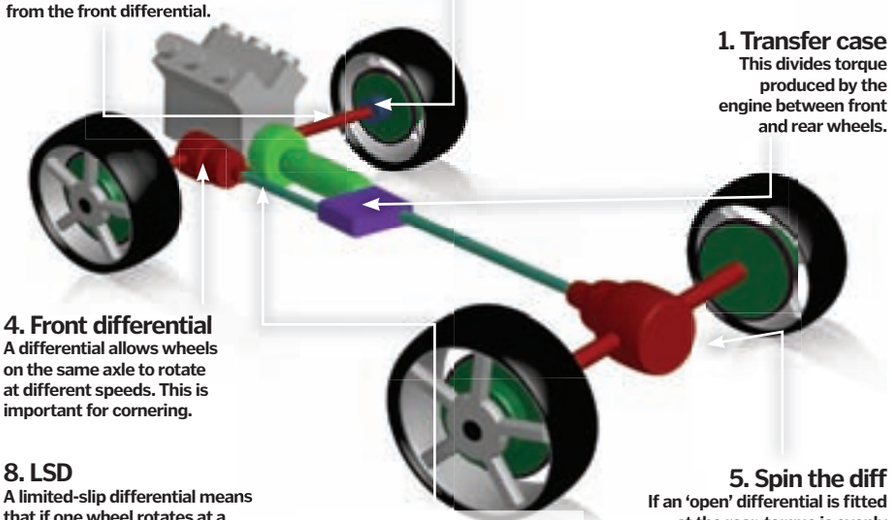
Driving all four wheels in a car at the same time is a complicated process, but at the same time it is the purest way to propel a car. Instead of two wheels out of the four transmitting the full energy of the engine to the road, that effort is spread more equally between all wheels.

There are two basic classifications of four-wheel drive that relate to whether the system is 'permanent' or not. Older and more basic systems are only part-time, with the all-wheel drive selected when conditions demand – these are the traditional 'four-wheel drive' vehicles. Most modern systems, however, are full-time, and these are known as 'all-wheel drives'.

There are different technical solutions in passenger cars, which depend on whether the basic car is normally front-wheel drive or rear-wheel drive. The more commonplace systems are found in dedicated off-roaders, though. These are engineered from the outset to drive all four wheels, incorporating the necessary transfer box, drive shafts and differentials.

Electronics are increasingly found in 4x4 systems, but the basic engineering remains the same. All send drive simultaneously forwards and rearwards. It is the management of how much drive is sent to which wheels and when that electronics oversee. This has enhanced the abilities offered by these vehicles.

Four square



2. Half shaft
Front half shafts are connected to the road wheels and transfer drive from the front differential.

3. Locking hub
On part-time 4WD systems, the front wheel hubs can be disconnected when running in 2WD mode.

6. Brains in the middle
Modern 4x4s frequently use 'torque-sensing' centre differentials. These constantly vary the drive split between front and rear axles according to grip available.

1. Transfer case
This divides torque produced by the engine between front and rear wheels.

4. Front differential
A differential allows wheels on the same axle to rotate at different speeds. This is important for cornering.

8. LSD
A limited-slip differential means that if one wheel rotates at a different speed to the other, the differential can partly 'lock' – ensuring drive still reaches the other wheel.

7. Front drive shaft
The front drive shaft transmits drive forwards from the transfer case to the front differential.

5. Spin the diff
If an 'open' differential is fitted at the rear, torque is evenly split between the wheels. So if one raises off the ground or spins, it can take on no torque, and neither can the other.

Now we're torquing

The product of an engine is a physical twisting force; this turns the drive shafts and moves the car. This is known as torque. Four-wheel drive systems work by optimising the spread of this force between all four wheels.

If you apply too much torque to a wheel, the tyre will slip. However, in four-wheel drive cars each wheel carries 25 per cent of torque, rather than 50 per cent. It means a more measured distribution of force across all four wheels.

Head to Head
FOUR WHEEL DRIVE

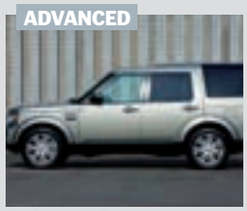
TRADITIONAL

1. Land Rover Defender
A mechanically elegant system of transfer box, locking differentials and low-ratio gears has done the Defender proud for decades, and remains loved by those seeking all-grounds tenacity.

MODERN

2. Land Rover Freelander
Electronics mastermind the four-wheel drive system here, with most of the Defender's hardware replaced by a hi-tech rear differential 'Haldex' clutch.

ADVANCED



3. Land Rover Discovery 4
Here, traditional and modern 4WD combine – with cutting-edge electronics controlling a highly evolved Defender-type mechanical system, the Discovery really can go anywhere. Almost...

DID YOU KNOW?

Part-time four-wheel drive that had to be selected when required has been in existence for decades. It is engineering that allows full-time four-wheel drive on the highway that was more challenging – but today, most four-wheel drives are 'permanent'.

DID YOU KNOW?

Life-saver

A Virgin Pendolino derailed in Cumbria, UK, on 23 February 2007. The cause was determined to be faulty points, and Virgin chairman Sir Richard Branson credited the train's build for limiting the loss of life to one.

An aircraft's wingtip vortex is made visible with coloured smoke

Wingtip vortices

What are they and why do they occur?

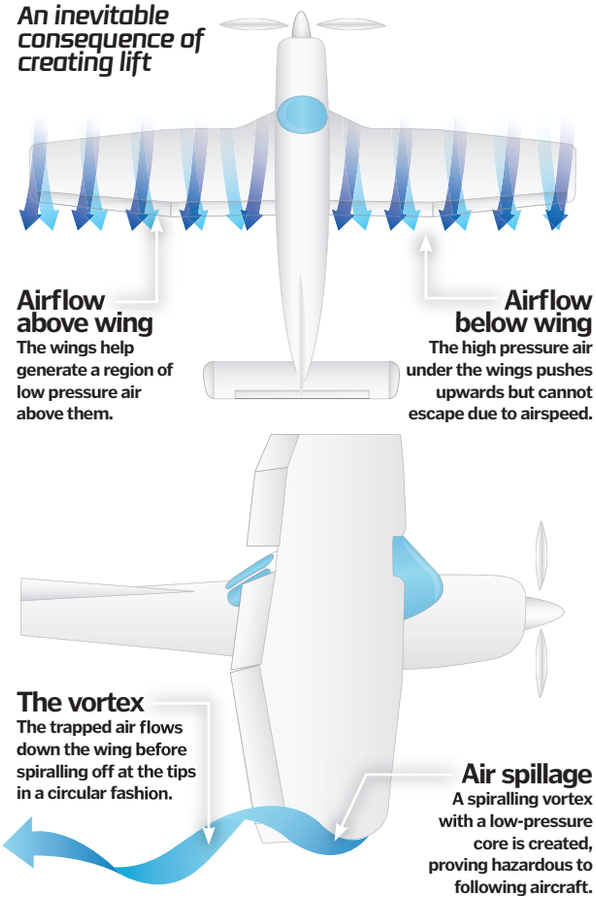
Wingtip vortices are circulating tubes of air that emanate from the tips of aircrafts' wings as they generate lift. Each wing has its own vortex and their cores spin at a great speed and at low pressure. They are formed when an aircraft's wings generate lift by creating a region of low pressure above them, causing the high-pressure air beneath the wings to migrate towards the top via the wingtips. Consequently, air flows from below the wing and out around the tip to the top of the wing in a circular fashion, causing a rotating tunnel of air behind it.

Wing vortices can cause severe hazard to aircraft that pass through their vicinity, especially during take-off and landing phases. This is because the vortices persist often for many minutes, drifting about runways on the wind. Due to their size they can spin and destabilise the plane with much more intensity than can be actively managed by its ailerons (these are the hinged control surfaces attached to trailing edge of most fixed wing aircraft), leading to severe difficulties.

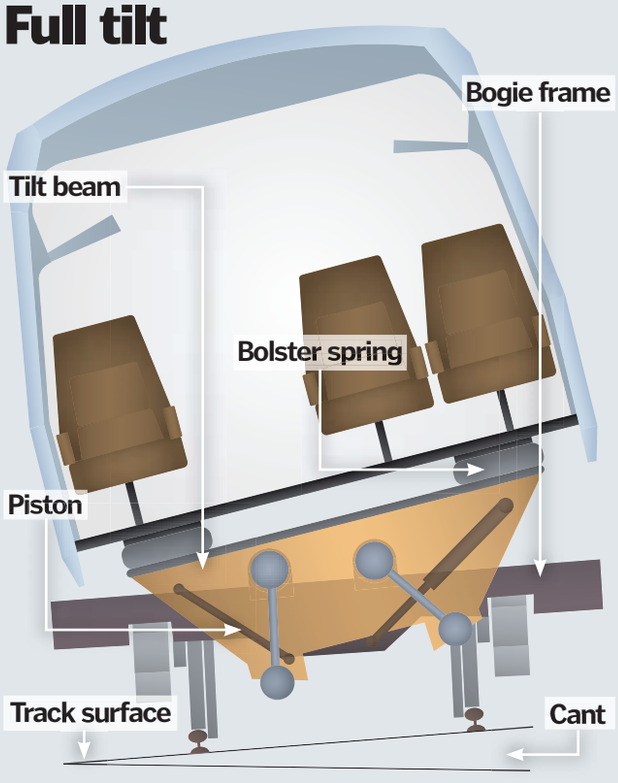
To counteract the negative effects that wingtip vortices have, it is standard procedure for air traffic controllers to leave a two to five minute gap between individual aircraft taking off or landing in the same airspace. This is especially necessary if a large plane is followed by a smaller aircraft.

What happens to the air?

An inevitable consequence of creating lift



Full tilt



Tilting trains

How high-speed trains can corner without sending passengers hurtling

Tilting trains provide the solution to the awkward jerking motion that is caused by the centrifugal force that pulls on a passenger when a train takes a corner at speed.

Virgin uses a train called the Pendolino, which uses powerful traction and tilting technology to lean into curves instead of slowing down, keeping journey times to a minimum. Tilting trains do not require special rails, instead the mechanism beneath the coach enables the train to corner quickly on regular mainline tracks. The wheels are attached to a hydraulic bogie, which is the chassis frame connected securely to the track. The bogie acts as a fulcrum in the centre, capable of tilting the coaches up to eight degrees in bends, using hydraulic or electromechanical jacks. Computerised pistons in the mechanism control the degree of tilt.

The Tiltronix technology inside the Pendolino provides either reactive tilting (using gyroscopes and accelerometers to determine the precise angle that is required) or anticipative tilting (using specific track information from a database together with on-board sensors).

© Virgin Trains

"It can seat up to 19 people in upper class comfort"

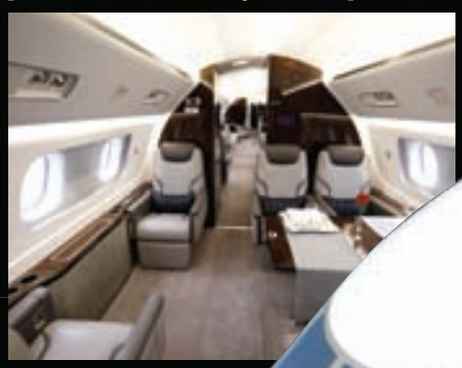
The luxury of the Lineage 1000 jet

A luxurious hotel in the sky? It's yours for a few million dollars

The best private jets offer more than just rows of seating and the Lineage 1000 includes a shower room, a double bed, a lounge and an office, a bar and almost everything else you need in a space that is three times larger than traditional business jets. It can seat up to 19 people in upper class comfort and the interior has been built to include five privacy areas, Wi-Fi and real-time flight displays, all thanks to the larger space and innovative interior design. On top of this the turbofan engine technology and fuselage interior design ensure low noise for passengers.

Safety has not been ignored and the pilot has a CMC (central maintenance computer) at hand to predict potential problems and offer solutions, plus an enhanced vision system to improve awareness at all times. Many of the systems are integrated into the jet itself, rather than added on, which reduces weight and other design enhancements increase approach steepness which is ideal for landing in smaller airports.

One of these enhancements is Smart Probe, which will sense airspeed, trim and altitude to ensure the most accurate positioning at all times. To sum up, the Lineage 1000 offers the ultimate flying experience thanks to the designers pushing the envelope in every single area of the design process.



Filthy-rich airlines, you are clear for take off

4. Catch up
Multiple large displays offer entertainment, internet and other facilities which will keep you busy no matter how long the flight is.

5. Need a restaurant?
The dining area is the perfect way to enjoy your in-flight meal, which is highly unlikely to be served on plastic trays.

6. Preparing food
The galley area is where food and drinks will be prepared. It can be sealed off from the rest of the cabin so as not to ruin the ambiance.

8. The serious stuff
Inside the cockpit are some seriously clever systems designed to aid safety and ensure the least disruption possible.

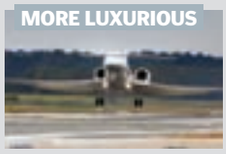
What the opposite to economy class looks like!

© Image courtesy of Embraer

Head to Head
LUXURIOUS PRIVATE JETS

LUXURIOUS

1. Falcon 7X
The Falcon 7X offers a mere 39-foot long cabin, but the advanced environmental systems still make for a very pleasant journey.



MORE LUXURIOUS

2. Gulfstream G650
The Gulfstream is designed to offer flexible comfort and succeeds, and at 53 feet offers great scope for individual cabin design.

MOST LUXURIOUS

3. Embraer Lineage 1000
With a cabin length of 84 feet the Lineage 1000 is easily the most luxurious thanks to the comfort and individualism offered in every corner.

DID YOU KNOW? *The Lineage 1000 interior can be configured from 25 different cabin modules*

Pure airborne luxury

1. Stay awake
The 84 foot long cabin offers a huge amount of space, which can be configured into various private areas for maximum comfort.

2. Get some sleep
A double bed will ensure you catch up on the sleep you need or you can just lie back and enjoy the large display on the wall.

3. Freshen up
A fully equipped luxurious bathroom will help you arrive at your destination fresh as a daisy and the fittings rival the best hotels.

7. More than a wardrobe
The 351 cubic feet walk-in baggage compartment lets you take your entire wardrobe with you and there's still room for your other luxuries.

No better place to join the mile high club

9. The power
The turbofan engines ensure the quietest and smoothest possible flight and also offer a longer range than many other private jets.

© Gulfstream Aerospace Corp

Know your engines

Jet engines are almost universally used to power private jets and passenger aircraft, but there are some significant differences between the type used on each. Private jets often use high-bypass turbofans, which are very quiet and offer enhanced fuel efficiency plus excellent thrust to ensure better performance. These engines are usually placed below the wing to reduce drag and turbulence, particularly during take off, which is crucial for a small passenger plane. Tests have proved that turbofan engines are highly reliable and that most pilots should never suffer an engine incident in their entire career. The Gulfstream G550 is one example which is powered by twin Rolls-Royce turbofans.

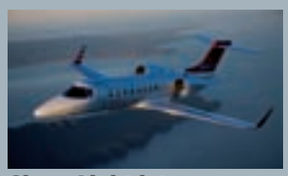
The Statistics

Lineage 1000

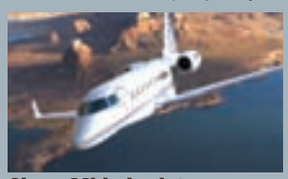
Manufacturer: Embraer
Class: Heavy jet
First flight: 26 October 2007
Wingspan: 28.72m
Length: 36.24m
Height (outside): 10.28m
Cabin height: 2m
Cabin volume: 115.7m^3
Cabin area: 68.85m
Weight max payload: 55,000kg
Unit cost: $42.95 million
Max speed/cruise speed: 480 knots/469 knots
Propulsion: GE CF34-10E turbofans (x2)
Ceiling: 12,497km

Know your jets

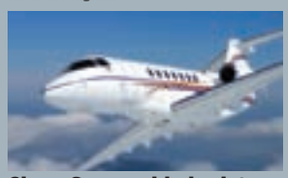
Class: VLJ
Passengers: 4-8
The VLJ (very light jet) is often used as an air taxi to travel between local airports in a country.



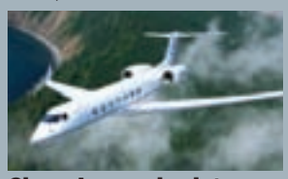
Class: Light jets
Passengers: 5-9
Light jets are similar to VLJs in their target market, but are faster and offer some extra luxuries for quick journeys.



Class: Mid-size jets
Passengers: Up to 18
Mid-size jets typically carry 8-12 people, but some can accommodate 18 people for short flights.



Class: Super mid-size jets
Passengers: Up to 19
These jets are designed to offer luxury for transatlantic flights and give more cabin space and luxuries.



Class: Large size jets
Passengers: Up to 19
Large size jets are designed for longer distances and New York to Tokyo is quite possible with high levels of comfort.

Class: Heavy jets
Passengers: 100s
Heavy jets range in size and can be privately hired. The Lineage 1000 is in this class, but is small compared to some.

"Each time the car is started, a new code is utilised"

Parking sensors

It's so easy to do your car some serious damage when parking, but thankfully this new technology can make us all parking masters

Parking sensors are now must-have technology. They enable us all to park ever-larger cars with expert finesse and avoid scrapes that can cost hundreds to repair. The most familiar type use ultrasonic technology – just like bats do!

When activated, these fire out high-frequency signals from a series of round sensors (usually four) attached to the bumper. When physical objects are detected within a set range, they will alert the driver via a visual or audible signal. Manufacturers programme the range of these signals within the logic board of the sensors; they can therefore be calibrated so the driver has an indication of how far away the object is.

Usually, widely spaced bleeps are issued. As the car gets closer to the object, the pause between these shortens, until a continuous tone is heard.

The alternative sensors are electromagnetic. These comprise a magnetic strip on the inside of the bumper – it is 'invisible' technology so is more aesthetically pleasing. When activated, a magnetic field is generated; from this, an elliptical magnetic field is sent out by a control unit. When something enters its range, the voltage in the control unit increases. The rate of this change is converted into a calibrated audible signal.

The car that (almost) parks itself

1. Smart sense
Active Park Assist uses a car's ultrasonic sensors in a smart way. Below a set speed, the two outside ultrasonic sensors on the bumpers scan sideways and measure sudden changes in distance that indicate the presence of a space.

2. Parking algorithm
The software for the Active Park Assist uses an algorithm that compares the length of the space with the known length of the car, plus the required 'manoeuvring space'.

3. The car steers itself
The Mercedes A-Class is fitted with electrically assisted power steering, so the motor can 'take over' the steering process. Engineers have defined the requisite steering movements to parallel-park, and stored these in the software.

4. Take out the guesswork
Once the system is engaged, it will steer in exactly the right way to perfectly park the car next to the kerb – there is no guesswork, as the steering profile of how to park that exact model has already been calculated.

5. Driver remains in control
The driver still controls brakes, throttle and gears for safety. The system still uses parking sensors in a traditional sense for distance measurement, too – the tolerances are no different as the movement of the car is still under the driver's control.

Car immobilisers

Forget car keys – nowadays car makers use advanced electronics to guarantee your car remains yours!

Thanks to electronic immobilisers, the days of thieves hotwiring cars are long gone. They have been mandatory on all new cars since the Nineties, and in their simplest form ensure the car cannot be started without a coded key fob or ignition – even if the ignition system is hacked.

In modern cars, the key fob transponder communicates directly with the car's electronic control unit (known as the ECU). By integrating the circuit into the car's central brain, it's virtually impossible for thieves to somehow hack into it. Because so many different aspects of modern cars are controlled by electronics, it is easy for makers to cut power supply to these components, therefore 'immobilising' the vehicle altogether.

The transponder itself is usually a coded chip. This is read by the car then the ignition is turned on. If it is missing – or if the coded chip doesn't match what the car is expecting – it will not start at all.

Many immobilisers use 'rolling code' technology. At the factory, a random table of codes is burned into the immobiliser unit, with a complementary one installed in the immobiliser tag. Each time the car is started, a new code is utilised – and the car will only start if the key and the immobiliser unit match each and every time.


Immobilisers are car thieves' worst nightmare

THE STATS JET SKIS

TOP SPEED **70mph** LARGEST NUMBER OF PASSENGERS **4** HORSEPOWER **260**

MAXIMUM FUEL CAPACITY **16.4 gallons** LENGTH **3.3m** WEIGHT **114kg**

DID YOU KNOW? *The JS400, the first jet ski to go into mass production, had wooden bulkheads*

It's yellow, but we can't all live in it...

© Sea-doo

Jet skis

Isaac Newton has no idea how much fun he's responsible for

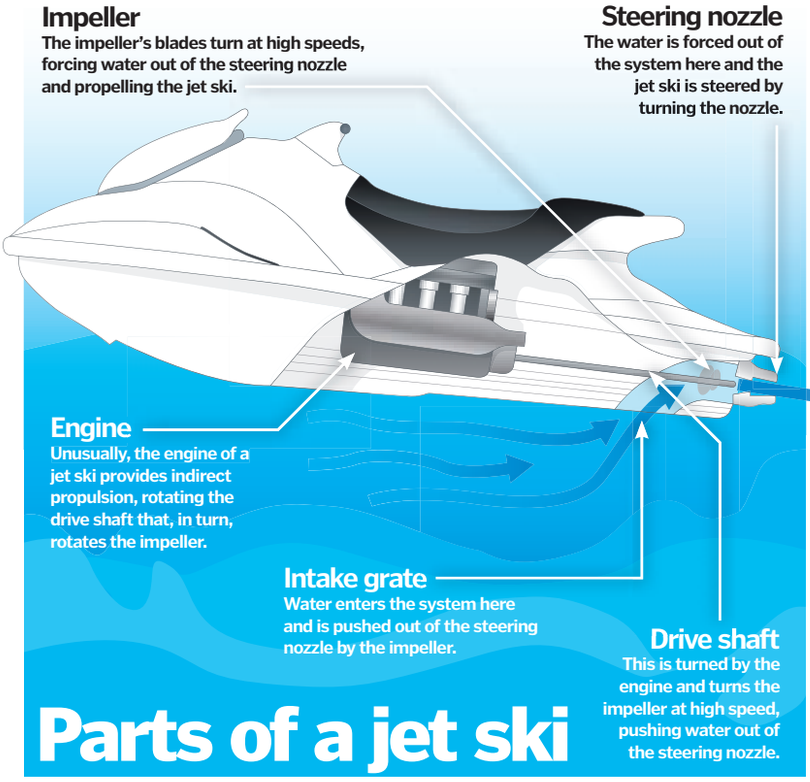
Jet skis work off Newton's third principle, that each action has an equal and opposite reaction. Here, the action is pushing a large volume of water out of the back of the jet ski and the reaction is pushing the jet ski forward through the water at speed. It's a remarkably simple principle which is achieved by using an equally simple device; an impeller drive.

The impeller sits inside a shaft that runs the length of the craft and is driven by the ski's engine. It's designed like a propeller and when the engine spins it, the blades of the impeller turn at speed, forcing water through the shaft and out through the nozzle at the rear of the ski, pushing it along.

Of course, everyone falls off every now and then, so modern jet skis all have a 'starter pin' or key that's placed in a slot near the ignition and is attached to the driver. If they fall overboard, the pin is yanked out and the ski coasts to a halt, preventing collisions and meaning the driver never has to swim too far to get back to it.

Turning on a wave

Jet skis are steered by controlling the direction of the steering jet at the rear of the ski. This is done by attaching two steering lines to the handlebars which run through the craft to either side of the nozzle meaning that if you turn left, the nozzle is pulled to the left, the jet ski turns left and vice versa.



Parts of a jet ski

Tamar lifeboat

"The Tamar outperforms its predecessor, the Tyne-class, in every department"

© RNLI/Phil Yeomans

5 TOP FACTS RNLI

Moolah
1 In 2009 it cost £147.7 million to run the RNLI. For every £1 raised by its volunteers, 84p went towards operations and 16p towards generating more income.

Busy
2 2009 was the RNLI's busiest year on record, with its lifeboats being launched 9,223 times (an average of 25 times a day). They rescued 8,235 people, an average of 22 people a day.

Pro
3 The only full-time team employed by the RNLI are based at Spurn Point on the mouth of the Humber River. This is due to the isolated position and extreme conditions.

Old
4 The RNLI was founded in 1824 as the National Institution for the Preservation of Life from Shipwreck, only adopting its current working name from 1854 onwards.

Royal
5 The headquarters of the RNLI is based in Poole, England, and is home to the Lifeboat Support Centre and National Training Centre. Both were opened by Queen Elizabeth II in 2004.

DID YOU KNOW? *The RNLI has over 330 lifeboats positioned around the United Kingdom and Ireland*

Tamar lifeboat

How It Works went to the Royal National Lifeboat Institution's headquarters in Poole, England, to check out its brand new state-of-the-art Tamar-class of lifeboat

Four years in the making, costing over £2.6 million and weighing over 30 tons, the Royal National Lifeboat Institution's new boat the Tamar is a serious piece of kit that has been designed from the ground up with one sole purpose in mind – to save lives. Named after the River Tamar, which forms the majority of the border between Devon and Cornwall, the Tamar is the most advanced boat in the RNLI's fleet and is capable of being launched from a slipway. It boasts a hoard of next generation technology too, including: fly-by-wire joystick steering, carbon fibre suspension seats that protect the crew from jolts in severe weather, and an integrated on-board Systems and Information Management System (SIMS). This allows complex tasks such as navigation and engine maintenance to be displayed on a single flat LCD screen, six of which are positioned around the vessel to allow crew to operate all the systems without moving from their seats. Further, the Tamar is fitted out with a hydraulically powered tailgate that allows a super-fast, pre-inflated Y-class daughter boat to be stored in the stern and released when necessary.

The Tamar also outperforms its predecessor, the Tyne-class, in every department. It is larger than the Tyne at 16 metres compared to 14 metres, allowing it to house and carry more injured persons and equipment. It is faster than the Tyne as well, hitting an impressive top speed of 25 knots compared to the Tyne's 17 knots; its daughter boat the Y-class is larger and faster than the Tyne's X-class, allowing a quicker sprint to larger stranded vessels. It also has improved ergonomics and build materials, granting it a higher endurance threshold and load bearing potential, ideal for when crashing through large waves, shunting up against other boats and rocks, and towing broken down or stranded vessels. In addition, the Tamar is kitted out with a host of new safety features geared towards keeping the crew and rescuees safe while at sea in rough conditions. For example, the SIMS system means that crew never ▶

The Statistics
Tamar lifeboat


© RNLI Nigel Millard

Length: 16m
Breadth: 5m
Draught: 1.35m
Weight: 31.5 tons
Crew: 7 (including doctor)
Material: Fibre reinforced plastic
Endurance: Ten hours at 25 knots
Speed: 25 knots
Power: 2 x 1,000hp turbocharged diesels
Propulsion: 2 x fixed pitch five-blade propellers
Fuel: 4,600 litres (1,000 gallons) propellers
Cost: £2.6 million


© RNLI Nicholas Leach

The RNLI's new Tamar lifeboat setting off for action out at sea

Tamar lifeboat

need leave their seat to control any part of the ship, allowing them to remain safely harnessed in instead of being thrown about the cabin. The on-board stretcher and doctors' seat have also been cleverly positioned in the main cabin too, allowing the doctor easy access to the patient while still strapped into his chair.

Importantly, however, the Tamar has been built with best practice and future proofing in mind, meaning that the boat and its systems have been designed to provide as much feedback and compatibility as possible. The Tamar's black box – which acts very much akin to an aircraft's – allows the coxswain to download and study any launch's report and statistics (such as: speed, distance, course, fuel usage, CCTV footage, communication patterns and efficiency, weather and climate graphs among others) in order to streamline future scenarios and tailor training and simulation programmes back at headquarters. The SIMS system is open too and runs off a Windows operating system, allowing future iterations of SIMS or Windows to be seamlessly installed into the Tamar without the need to remove and reinstall each command station.

This ease of use, compatibility and maximised feedback from the Tamar's systems is also important in consideration of the RNLI's current development on another even more advanced lifeboat. This is intended for launch in 18 months to two years time, and cross-compatibility between vessels and their ability to share data will help future crews to quickly find stranded vessels and persons and bring them safely back to dry land.

The RNLI is a charity and as such receives no government assistance in raising the massive amount of money that is required to operate it each and every year. If you wish to help the life-saving effort, though, there are various ways to get involved, both on a national and local level. For more information about the RNLI and its annual SOS national fundraising and awareness event, as well as where to find your local RNLI centre, please visit www.rnli.org.uk.


© Derek King


© Lo Ed Harris

RNLI staff during a training exercise in an indoor simulator at Poole

The history of the RNLI

Sir William Hillary is credited with founding the National Institution for the Preservation of Life from Shipwreck – later renamed the Royal National Lifeboat Institution – after he witnessed the destruction of dozens of ships from his home town on the Isle of Man. To achieve his goal, Hillary appealed to the Navy, the government and other financially powerful characters for help in forming 'a national institution for the preservation of lives and property from shipwreck.' Thankfully, his appeal did not go unheaded as London MP Thomas Wilson and West India Merchants Chairman George Hibbert backed and supported him, leading to the foundation of the charity on 4 March 1824.

Before Hillary set up the RNLI, the islands of Britain and Ireland had always been at the mercy of the sea. Indeed, in the early 19th Century there was an average of 1,800 ships wrecked a year around their coasts, and communities would be powerless to help. There are some records of individual lifeboats being operated, however they were sporadic and relied on using whatever boats and equipment they could get their hands on. It wasn't till 1789 that a standardised life saving boat came into existence, when a group of businessmen from the north of England ran a competition to design one.

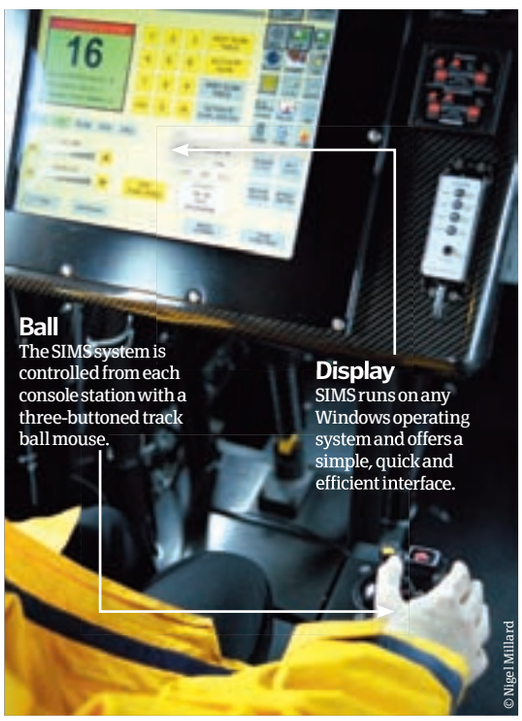
DID YOU KNOW? *The RNLI was set-up on 4 March 1824*

Rescue
When transporting stranded civilians from larger vessels, harnessed crew help them onto the Tamar here.

©RNLI / Nigel Millard

The upper steering area of the Tamar

© Nigel Millard



Ball
The SIMS system is controlled from each console station with a three-buttoned track ball mouse.

Display
SIMS runs on any Windows operating system and offers a simple, quick and efficient interface.

© Nigel Millard

RNLI staff during their annual 'SOS' fundraising day

© Nathan Williams

Interview
John Nurser
RNLI principal engineer

How It Works spoke to Royal National Lifeboat Institution principal engineer John Nurser about the Tamar lifeboat and the day-to-day realities of search and rescue

How It Works: The Tamar is the RNLI's newest and most advanced lifeboat, can you tell us a little about what makes it better than its predecessor?
John Nurser: The Tamar is our newest class of boat and has been in operation for the last couple of years. It is very advanced for a boat of its size and class and has been designed to run off a slipway. In essence, it has been updated to run in the 21st Century – so we have installed more integrated systems on the boat to deal with navigation, the monitoring of mechanical systems and safety and security protocols, fitted faster engines that allow it to hit 25 knots (29mph) in calm conditions and 17 knots in storm conditions and implanted better seating for the crew members. Indeed, one thing that has always been a problem in boats of this size – especially in bad weather – has been the seating. So we have spent a lot of time, effort and money on designing and fitting new spring-cushioned carbon fibre seats, which have the major benefit of not being able to bottom out, taking the majority of the thump out of bumpy journeys. As after all, when the weather gets bad, the best place for both crew and rescued persons is in a secure seat.

HIW: What about the individual crew's roles on board? What benefits do the new systems and features in the Tamar grant them?
JN: Previously crew were strapped into their individual seats and fulfilled their roles from there, with the boat's equipment spread around the wheelhouse. So the navigator would have the radar open, the helmsman would have things like tachometers running in front of him, and the mechanic would have engine displays and readouts on display, with only the person in that individual seat able to see and control any of these aspects.

This meant that there was no versatility or redundancy, so what we have done on the Tamar is put in several screens and all of them can show any of the information, with protocols in place to avoid conflicts in operation, as obviously you don't want two people fighting over control of any one aspect. So, for example, only one person can do certain things on one screen at one time, however all elements can be controlled from any screen around the wheelhouse and this means that if one person is busy during a rescue and someone else wants to quickly view their role's information, they can bring it up on their screen and if necessary take control, and all without ever leaving their seat.

HIW: Focusing on the boat's complement for a moment, what different roles/personnel is each Tamar crewed with?
JN: Well, there's one main role and that is to go out and rescue people. Sometimes the search bit is the big bit, we may have somebody lost or a diver fallen overboard, and then that part of the role becomes larger as we may not be sure where they are. Fairly often the search bit is reduced as there is lots of electronic kit that can identify positions and more and more people going to sea have radios and mobile phones, so when they get into trouble they can call in and report where they are. Clearly the boat has to have technology to help any search but, more often than not, the best piece of equipment for finding people are standard human eyeballs, so when we designed the Tamar we ensured that all the crew had good access to viewing windows with good wide viewing angles.

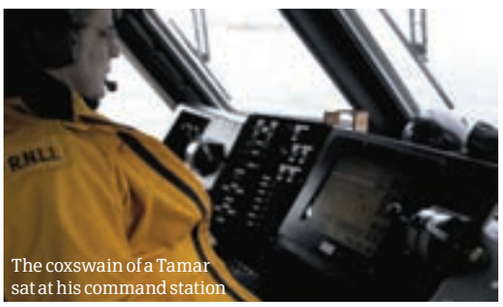
In terms of the individual personnel on board, the Tamar will usually have between four and six people on board during an operation, however the boat is technically fitted with seven seats so a doctor can be carried too. So if we know that someone has been badly injured in an incident we will always try and take a doctor or paramedic. The crew itself will usually comprise of a coxswain, who is in charge of the entire boat, a helmsman – the person in charge of actually steering the boat – two navigators and a mechanic, who looks after all the mechanical systems and undertakes maintenance, as well as secondary mechanics and junior crew. Importantly, though, when undertaking any rescue operation, one of the most important roles – one in which all members take part in – is just hands-on manual work. As if you are trying to go alongside a big ship that is heaving all over the place the only way you can get the people off is for them to jump down, and for that you need lots of pairs of hands.

HIW: Do the RNLI have any protocols in place dictating how fast their crews need to be out on the water after receiving an emergency call from the coastguard?
JN: Yes, we aim for all of our crew members to be assembled and ready to leave in ten minutes. So in order to be a crew member you have to live within a certain distance of the lifeguard station to ensure you can get there in that short amount of time.

HIW: What percentage of each crew tend to be volunteers, compared with maritime professionals?
JN: Most of them are. Every all-whether boat has at least one full-time crew member though. Because they have big powerful engines we basically need a trained mechanic to maintain them and look after them at sea. In some areas where they get a lot of calls out and it's perhaps a difficult area, they may also have a full-time coxswain as well.

HIW: What qualifications or accreditations do people need in order to join?
JN: Basically, if you take the average lifeguard, they have wandered to the lifeboat station and fancy being on the crew. So they are taken on as probationers for a while and they are asked to turn up at various unsociable times – such as the middle of the night – so that the coxswain and management get an idea of what they are like and if they are dedicated. Basically, to answer the question: 'Are they going to make it as a life guard?' If they pass that informal test they then begin what we call competence-based training. Here the management and the coxswain look at the competences they have and they are trained to use the various machinery and systems, as well as best practices in terms of safety and rescuing.

HIW: How does the RNLI raise the money to keep it running?
JN: The UK government gives us no assistance and no money, so it is all raised through donations. Quite a lot of that is legacy donations left in people's wills and the rest is raised voluntarily through fundraising, mostly at a local level. People can also take up membership with the RNLI, which means they pay a monthly fee and receive a magazine and are invited to events, which also helps us make money.



The coxswain of a Tamar sat at his command station

HMS Victory

One of the most famous ships of all time, HMS Victory was instrumental in ensuring British naval supremacy during the late 18th and early 19th centuries

The only surviving warship to have fought in the American War of Independence, the French Revolutionary War and the Napoleonic wars, the HMS Victory is one of the most famous ships ever to be built. An imposing first rate ship of the line – line warfare is characterised by two lines of opposing vessels attempting to outmanoeuvre each other in order to bring their broadside cannons into best range and angle – the Victory was an oceanic behemoth, fitted with three massive gundecks, 104 multiple-ton cannons, a cavernous magazine and a crew of over 800. It was a vessel capable of blowing even the largest enemy vessels out of the water with magnificent ferocity and range, while also outrunning and outmanoeuvring other aggressors.

Historically, it was also to be Vice-Admiral Horatio Lord Nelson's flagship during the epic naval battle off the Cape of Trafalgar, where it partook in the last great line-based conflict of the age, one in which it helped to grant Nelson a decisive victory over the French and Spanish but at the cost of his own life.

Turner's famous painting of the Battle of Trafalgar in which the HMS Victory is shown in the midst of battle

The Statistics

HMS Victory

Class: First rate ship of the line
Displacement: 3,500 tons
Length: 227ft
Beam: 51ft
Draught: 28ft
Propulsion: Sails – 5,440m²
Speed: 9 knots (17km/h)
Armament: 104 guns
Complement: 800

Sails

The HMS Victory is a fully rigged ship, with three sets of square sails covering 5,440m². The breadth of the Victory's sails allowed it to sport a maximum top speed of nine knots when operational, which was for the time very impressive considering its size and weight. During the 18th and 19th centuries a fully rigged ship necessitated three or more masts each of which with square rigging. At full flight the Victory could spread a maximum of 37 sails at one time and could carry 23 spares.

Crew

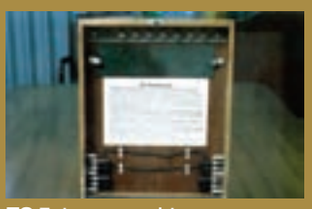
There were over 800 people on board the HMS Victory, including gunners, marines, warrant officers and powder monkeys among many others. Life on board was hard for the sailors, who were paid very little for their services and received poor food and little water. Disease was rife too, and punishments for drunkenness, fighting, desertion and mutiny ranged from flogging to hanging.

This month in History

Here at **How It Works** it's recognised that – contrary to the quote often attributed to Winston Churchill – there's a great deal more to British naval history than rum… er… more rum and the lash (ahem). Just take a look at the cutaway of the incredible warship that was HMS Victory. When you've finished looking at the images read on to find out what made this vessel so special. There's plenty more for the history buff including a look inside the Statue of Liberty and an explanation of how the Enigma code machine worked.

76 Water wheels

77 The Statue of Liberty



78 Enigma machine

HISTORY

5 TOP FACTS HMS VICTORY

Back-up
1 Upon completion, the HMS Victory was not put directly into use, but was moored in the River Medway for 13 years until France joined the American War of Independence.

Wood
2 Building the HMS Victory required over 6,000 trees to be cut down, 90 per cent of which were oak. The other ten per cent consisted of elm, pine, fir and lignum vitae.

Mirabilis
3 Victory was commissioned to celebrate the Annus Mirabilis (year of miracles) of 1759, where the British achieved great military success against French-led opponents.

Trafalgar
4 Victory was Nelson's flagship during the famous Battle of Trafalgar in 1805 which, despite Nelson being mortally wounded, saw the British Navy win a decisive victory.

Rest
5 The HMS Victory was docked down in No 2 Dock Portsmouth – the oldest dry-dock in the world – in 1922 due to deterioration of its bodywork.

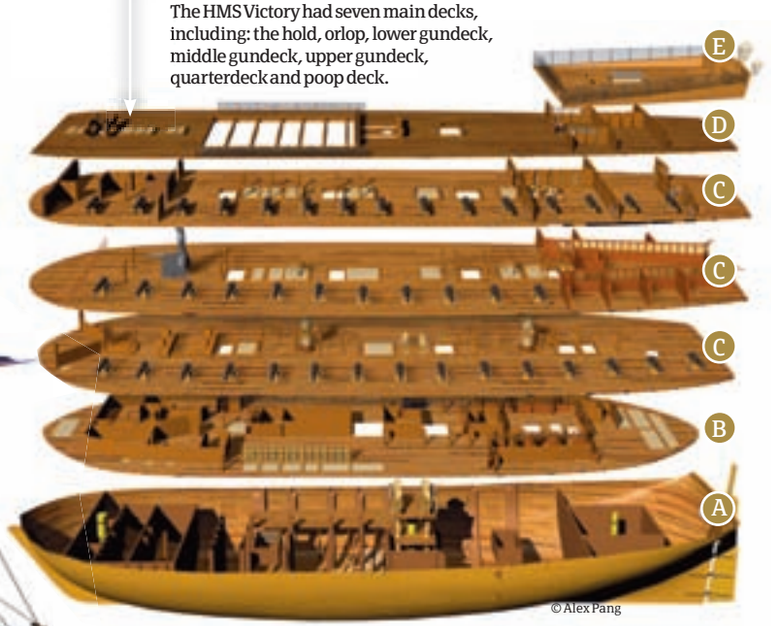
DID YOU KNOW? *HMS Victory cost £63,176 when finished in 1765, the equivalent of roughly £7 million today*

Masts

The HMS Victory sported a bowsprit (the pole extending beyond the ship's head), fore mast, main mast, mizzen mast and main yard. A total of 26 miles (41.9km) of cordage, as well as 768 elm and ash blocks, were used to rig the ship.

Decks

The HMS Victory had seven main decks, including: the hold, orlop, lower gundeck, middle gundeck, upper gundeck, quarterdeck and poop deck.



© Alex Pang

(A) The hull
The hull was the largest storage area on the ship where up to six months of food and drink could be stored, as well as any excess supplies.

(B) The orlop
The only other deck below the waterline, the orlop was another storage area and also habitation deck for certain crew members such as the purser.

(C) The gundecks
Housed the majority of the Victory's cannons, with a tiered arrangement from top to bottom (largest cannons on the bottom, smallest on the top). These decks also housed the majority of the crew and Royal Marines, sleeping in hammocks suspended from battens fixed to overhead beams. The lower gundeck also acted as mess deck, the space where the crew would live and eat.

(D) The quarterdeck
The nerve centre of the ship, where its commander dictated its manoeuvres and actions often under heavy gunfire from rival vessels.

(E) The poop deck
Located at the stern, this short deck takes its name from the Latin word puppis, which literally means 'after deck' or 'rear deck'. This deck was mainly used for signalling, but also gave some protection to the man helming the ship's wheel.

Cannons

As a first rate ship of the line, the Victory was a three-gundeck warship with over 100 guns. In fact, the Victory was fitted with 104 cannons: 30 x 2.75 ton long pattern 32-pounders on the gundeck, 28 x 2.5 ton long 12-pounders on the middle gundeck, 30 x 1.7 ton short 12-pounders on the upper gundeck, 12 x 1.7 ton short 12-pounders on the quarterdeck, and 2 x medium 12-pounders and 2 x 68-pounder carronades on the forecastle.


© Alex Pang

© Alex Pang

"It's a simple principle adapted the world over"

Water wheels

Harnessing the power of water for thousands of years

Invented by the ancient Greeks, the water wheel is a piece of technology that has not only spread worldwide but also continues to be used today. A large wooden or metal wheel is placed – usually vertically on a horizontal axle – into a body of water. Blades or buckets on the outside rim 'catch' the water, creating a driving force that turns the wheel and, via either a ring gear or drive belts, then turns heavy machinery. It's a simple principle adapted the world over for everything from grinding linen to make paper to pumping water from mine shafts.

Types of water wheels

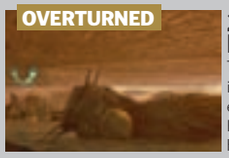
Breastshot
Breastshot wheels take their name from the fact that the water falls and strikes buckets near the centre of the wheel's edge or just above it. The wheel is set into a masonry 'apron' to ensure the water stays in the buckets as they move downward.

Overshot
These are powered by the water being channelled over them and down onto one side. The water collects on one side and the weight of the heavier buckets turns the wheel. They gain additional energy as both the weight of the water and the force of its movement are transferred.

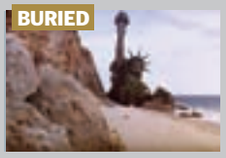
Pitchback
Pitchback water wheels work off the same principle as overshot wheels, with one exception: the water hits the back of the wheel instead of the front, harnessing gravity once again. The design ensures that the full potential energy of the water is harnessed.

Undershot
Undershot wheels are powered by water striking paddles at the bottom of the wheel. While they are the least efficient in terms of energy produced, they have the least impact on the body of water as they do not require any major modifications to the flow of the river.

1. The Day After Tomorrow (2004)
When New York is devastated by global warming, the Statue of Liberty is frozen. Here she becomes a symbol of the end of civilisation.



2. Independence Day (1996)
The statue is toppled by an incoming force of extraterrestrials and lands in the Hudson River. Will Smith ensured humanity had the last laugh...



3. Planet Of The Apes (1968)
The statue is used to symbolise an apocalyptic revelation. She appears during the finale of the film – half buried in sand.

DID YOU KNOW? *The Statue of Liberty has been the site of bungee jumps, suicides and even a birth*

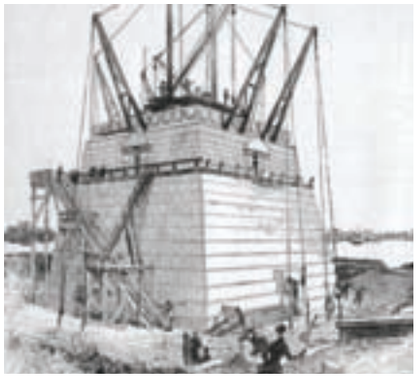
The Statue of Liberty

The Statue of Liberty was officially titled 'Liberty Enlightening the World'. It was built as a monument commemorating the centenary of the Declaration of Independence

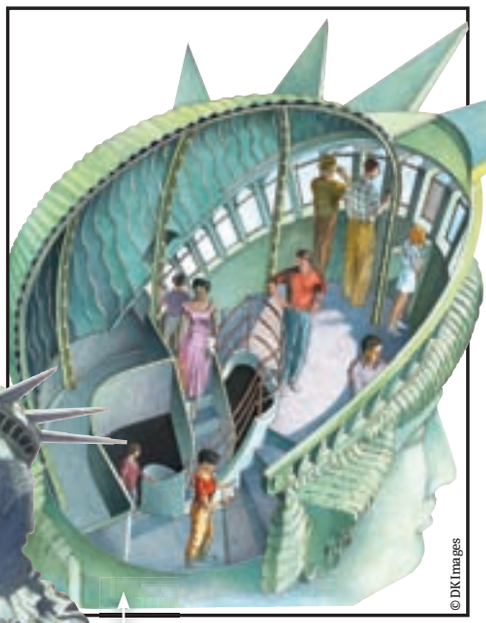
Constructed by the French, the Statue of Liberty was designed as a colossal copper statue. Gustave Eiffel, the designer of the Eiffel Tower, was asked to build a massive iron pylon and a skeletal framework to act as the support for the sculpture. While remaining fixed to its steel frame, the structure was able to move in the wind – subsequently, wind speeds of 50 miles per hour have been recorded, and the statue has been known to sway up to three inches under pressure.

The pedestal, crafted from Scottish sandstone, was built in the USA. Once this was erected, it was time to assemble the statue proper. Parts of the statue were shipped from France. They arrived in 350 pieces and were packed into 214 crates. It took four months to assemble the statue and secure it on the pedestal. The pedestal is supported by two sets of iron girders which are connected by iron tie beams – these extend upwards into the framework of the statue creating a strong link from the ground. The Statue of Liberty was originally designed as a lighthouse and functioned as such from 1886 to 1902. It housed an electric light that could be seen several miles out to sea.

The construction process began by creating a wooden frame and mould



Torch
In 1986, the old torch was replaced. It is now displayed in the lobby. The current torch is illuminated by large spotlights that cast a magnificent reflection on its gold plating.



Observation platform
The observation platform is situated at the top of the statue. There is space here for 30 people. The platform affords a magnificent view through 25 windows in the crown.

Ladders to the right arm
This area has been closed for many years. The ladders are used by the maintenance team when repairs are necessary.

Tablet of the Law
The Tablet of the Law is situated in the left hand of the statue which represents the Goddess of liberty. It bears the Roman letters for the date 4 July 1776, American Independence Day.

Staircases
There are two spiral staircases that wind around a central column. One staircase is ascending while the other is used for the descent.

Girders and staircases
Here we see the original skeletal frame of the Statue of Liberty. Around it we see the staircases that lead to the viewing platform.

Foot of the statue
Six stories above the base, this landing takes the visitor to the fourth level which is situated at the foot of the statue. From here the visitors can access the spiral staircase that leads to the viewing platform 12 stories above.

Pedestal
Once the visitor enters through doors at the base of the pedestal, they find a stairway that leads up to the second level.

Pavement
The pavement is situated between the walls and the lawns. It allows the visitors to take in a vertical view of the statue and leads them to the door of the monument.

The Statistics
Statue of Liberty

Sculptor: Frederic Batholdi
Year built: 1879-1884
Purpose: The statue was a commemorative gift given by the French to their fellow republicans in the USA.
Location: Liberty Island, NYC
Height: 151 feet, 1 inch
Steps: 354
Weight: 204.1 metric tons

"It was capable of producing billions of different combinations"

The Enigma machine

Inside the machine that helped the Allies decipher messages and shorten the war

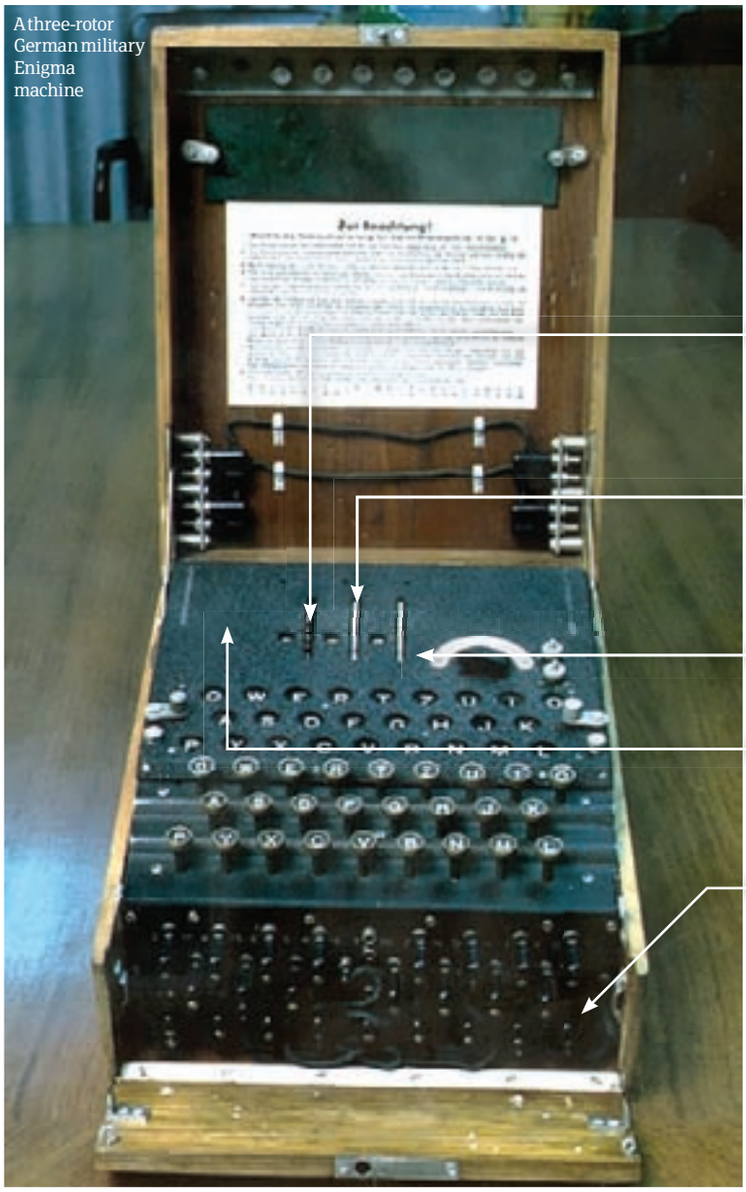
Used by the German secret services, Enigma was an electro-mechanical machine that relied on a series of rotating wheels to scramble messages into a chaotic ciphertext. It was capable of producing billions of different combinations and was successfully designed to encrypt and decode highly sensitive messages.

Although it's been used since the early Twenties it's closely associated with the codebreakers of the allied forces – the British and Americans used the machine to secure intelligence from the Germans during WWII.

To unscramble messages, the codebreakers needed to know the Enigma setting used by the German operator before the message was encrypted. The German operators – both the sender and receiver – had to utilise their machines on identical settings recorded in codebooks and established before operations commenced.

Codebreakers approached enemy messages using a method called 'Friedman's Index of Coincidence', which relied heavily on the mistakes and repetitive actions of the German operators in order to identify security flaws. This meant they could recognise patterns within the enemy codes and cryptanalyse their communications.

Mathematicians at Bletchley Park went on to develop the Bombe machine, designed to identify repetitive words and phrases in the messages and help them to guess at the meaning of the shorter parts of the messages. These were called 'cribs'.



A three-rotor German military Enigma machine

The machine

The Enigma machine consisted of a keyboard, a group of rotating discs and various stepping components that turned the motor shafts and discs when the operator pressed a key. The wide variation of the number of rotor positions enabled the operator to create different cryptographic symbols, or letters, after each key was depressed.

Rotors

The rotor was the most important part of the machine, it was opposed by an electrical conductor. The rotor could be set into various positions enabling it to produce random letters.

Stepping wheel

Based on a ratchet and pawl mechanism, the wheel had a series of teeth that corresponded with the letters of the alphabet. The wheel controlled the position of the rotor.

Entry wheel

The entry wheel connected the plugboard to the rotor system.

Reflector

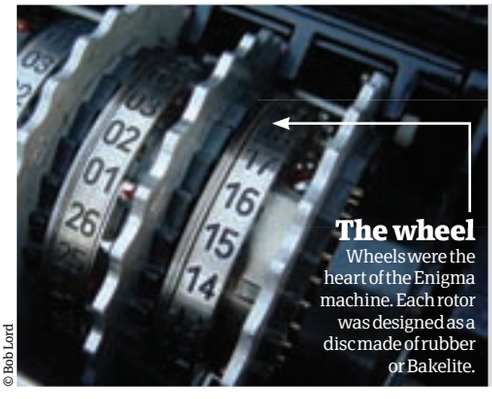
The reflector redirected the electrical currents back through the rotors but by a different route enabling the machine to create many varied and complex codes.

Plugboard

The plugboard – through a complicated and variable wiring system – allowed the operator to alter, and enhance, the code patterns. The plugboard was essential to the machines ability to encrypt messages.

Accessories

These included a small printer that would feed information onto a paper ribbon. A remote lamp panel, which enabled the operator to read the decrypted text and an extra plugboard switch that could be turned to 40 different positions.



The wheel
Wheels were the heart of the Enigma machine. Each rotor was designed as a disc made of rubber or Bakelite.

© Bob Lord

The Enigma machine rotor

The Enigma rotors were coding cylinders, or code wheels, set on a rotor shaft. The rotors were arranged along a shaft – they could be altered in component when an individual pressed a key. The continual movement of the rotors resulted in a variant cryptographic substitution after each key was pressed.

Station X and Codename Ultra

Known as Station X, Bletchley Park was the most important cipher school in England. While various ciphers were decrypted there, the German Enigma codes remain fixed in the public imagination.

This intelligence work was known as 'Codename Ultra' and early government employees went under the guise of 'Captain Ridley's shooting party'. Many codebreakers were graduates of Oxford and Cambridge universities and kept their roles undercover despite the fact that by 1939 the military held many of the rooms at Bletchley Park. Listening stations, called Y-stations, were situated in various parts of the country. They gathered 'raw signals', which were then sent for processing to Bletchley Park.

BRAIN DUMP

Because enquiring minds want to know...

Ask your questions

Send us your questions using one of the methods below and we'll get them answered by our team of experts

Facebook: search for "How It Works"
Twitter: http://twitter.com/HowItWorksmag
Email: howitworks@imagine-publishing.co.uk
Web: www.howitworksdaily.com

HOW IT WORKS EXPERTS

sciencemuseum

Rik Sargent
Science Museum Explainer

Rik is an Explainer in the Science Museum's Launchpad gallery. When Rik isn't blowing up stuff or putting people in giant bubbles he trains the Explainer team in the principles of science.

Dwain Anthony Clarke
Science Museum Explainer

Dwain most enjoys interacting with people and making them laugh. He has a history of working with young people with learning difficulties and disabilities. He also suffers from a biscuit addiction.

Laura Brettle
Science Museum Explainer

Laura has a degree in astrophysics and has been working in the museum for four years. She loves performing exciting interactive shows, getting to share her passion for science with others.

How do fire breathers not burn themselves?

Harry Sanders

■ Preparation is key to the art of fire breathing and only through keeping safety in mind at all times can even the most gifted fire breather perform uninjured. To do this artists focus on three main things: fuel type, technique and wind direction. The first is arguably the most important factor, as if a fuel with a low flash point is chosen (such as alcohol) then it becomes incredibly difficult to control the resulting flame, as the substance will be highly volatile at low temperatures. Instead, artists will use a substance like paraffin, which has a relatively safe flash point. Secondly, artists will have honed their technique of inhaling the substance, adding a small amount of it in liquid form to their mouth and then breathing the resultant vapour/liquid over their energy source (usually a lit torch). Thirdly, fire breathers will always take note of wind direction at all times in order to remove the possibility of having the resultant flame blown back over them.

HIW

Why does jelly wobble?

Cathy Lewis

■ Jelly is a soft semisolid containing gelatine. Gelatine is processed from the protein collagen found in skin and bones, (wouldn't advise eating jelly if you are a vegetarian). The molecules in gelatine are intertwined in a triple helix, as they are mixed with hot water their bonds break, they unravel and become long stretchy wriggly lines. As the water cools down, the helices start to reform and cross-linking occurs. This creates supermolecules that are so long they span across the whole jelly in a three-dimensional web, and water gets trapped in the spaces giving jelly its wobble.

Dwaine Anthony Clarke

Why do apples turn brown once you've cut them open?

Pete Turner

■ Apples, and many other fruits, contain an enzyme called tyrosinase as well as iron containing phenols. When the apple is cut open, the phenols react with the oxygen in the air in a process known as oxidation. The tyrosinase enzyme speeds up the reaction and this whole process is called enzymic browning. This process can be slowed by the addition of lemon juice, which lowers the pH and essentially stops the enzyme from working.

Rik Sargent

What is the hardest form of plastic?

Freda Dixon

■ The hardest forms of plastic include plastic that has been mixed with other types of materials such as a very recent discovery by a team of Bangalore researchers where they strengthened ordinary plastic with nano-diamond (incredibly, tiny bits of diamond invisible to the naked eye), a sheet of layered carbon and tiny carbon cylinders. Also polycarbonates, which are commonly known by the trademark name Lexan, are a type of thermoplastic polymer, which, due to their durability, are widely used in bullet-resistant 'glass'.

The softest forms of plastic can be runny such as polymer clays, which are very malleable and can also include liquid forms.

Rik Sargent

Is a flame a solid, liquid or gas?

Daniel Price

■ A flame is the part of a fire that we see and feel. Neither of these is a material but what produces them is, and therefore is in a particular state of matter while the flame exists. For a fire to be produced we need heat, oxygen and a fuel. When these three things are combined, a chemical reaction takes place, which produces new compounds. In the case of wood we get charcoal and a gas made of carbon, hydrogen and oxygen. As this gas is heated it breaks down and forms new substances in the form of water, carbon dioxide, and other products. The flame produced by these gases releases energy in the form of light and heat, hence a flame. The colour of the flame depends on how efficiently the fuel is burning and what material is being burned. To prove these substances are a gas, scientists can analyse the light from the flame using a method called spectroscopy, which will show what elements are present.

Laura Brettle

Why do we sleepwalk?

Jack Duff

■ As with most brain-related questions there is no direct evidence or cause as to the exact underlying mechanism for what makes us sleepwalk, but nevertheless there has been some interesting research into this area. You may be aware that there are different stages to the sleep cycle and it has been found that physical activity – including sleepwalking – only occurs during the non-rapid eye movement (NREM) cycle of deep sleep.

It is thought that sleepwalking occurs due to normal physiological systems being activated by the brain at inappropriate times. Research has shown that there may be genetic involvement which means tendencies to sleepwalk can be passed on from one generation to the next. It has also been observed that sleepwalking occurs most often in childhood, which could be to do with children spending more time on average in the deep sleep part of the sleeping cycle. Several studies have shown that sleepwalking can be associated with stress, fever and sleep deprivation.

There is a chemical messenger in the brain called gamma-aminobutyric acid (GABA), which acts as a neural inhibitor to certain activity of the brain. It has been speculated that a lack of this, or an underdeveloped system which inhibits the activity of the brain, could be a cause.

Rik Sargent

sciencemuseum

What's on?

how scientists are working to improve our understanding of it.

FAMILY EVENTS...

Fake ID

■ 26 July - 3 September (excludes 17 and 18 August) ■ Free ■ Who Am I? gallery, first floor
Join us on this fun interactive trail where you can try to steal an identity and discover what makes everyone different.

Lego® Landscapes

■ 17-18 August ■ Free ■ Flight Gallery, third floor
Help build a giant, flight-inspired Lego display. Assemble an aircraft, construct a Concorde or build an air-balloon and watch as a team of Lego master builders integrate your creation into a giant flight-themed scene.

SCIENCE MUSEUM LATES...

The Final Launch

■ 16 September ■ Free ■ Science Museum's Dana Centre
With the Space Shuttle on its last few missions, blast off into an exploration of its legacy. Find out how NASA's reusable vehicle changed our view of the cosmos and learn what's next for manned space exploration.

Music of the Mind

■ 17 September ■ Free ■ Science Museum's Dana Centre
A night of musical performance and scientific exploration, with musician Finn Peters. Discover the innovations in brain-computer technology that allow us all to compose music from our own brain waves.

For further information visit the What's On section at www.sciencemuseum.org.uk/centenary.

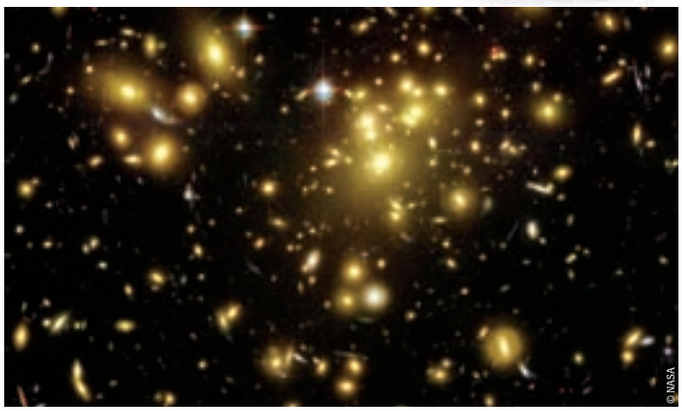
Visit the Museum
Exhibition Road, South Kensington, London SW7 2DD. Open 10am – 6pm every day. Entry is free, but charges apply for the IMAX 3D Cinema, simulators and some of the special exhibitions.

How are decibels measured?

Emma Barrett

■ What makes a particular noise louder than another is how much energy is put into producing it, and we measure and express this loudness in decibels. We can measure decibels with a decibel meter. Sound is a vibration passed from one molecule to another and when it reaches our ear the vibration is converted into a sound by our brain. The larger the vibration the louder we interpret the sound. A decibel meter contains a very sensitive microphone that acts a little bit like our eardrums and measures the size of the vibration caused by the sound wave. This is then interpreted into an electrical signal and gives out a reading in decibels. Essentially, the more the microphone vibrates the larger the decibel reading.

Laura Brettle



What's the farthest out into space we've seen?

James Davison

■ The farther you look into space, the farther back in time you'll see. This is because light has a speed and it takes time for that light to travel across the universe. Because of this there is a limit to what we can see. It also means there are regions of space which we will never see because they are so far away, even though the light is travelling towards us, the space itself is expanding faster (nothing moving through space can travel faster than light, but the expansion of space can).

We calculate the age of the universe to be around 13.7 billion years old. Therefore we can only see light that has been travelling for this time. However, the rate of expansion of the universe has been changing. The most distant observed object is GRB 090423 which was a gamma ray burst detected in 2009, most likely caused by a star which collapsed when the universe was around 600 million years old. The light we're seeing from this object has been travelling through the universe for about 13 billion years yet we are seeing the object as it was when it was closer to the Earth, about 36 million light years away.

However, in the 13 billion years that the photons of light given off by GRB 090423 have been travelling, that distance of 36 million light years has stretched to about 46 billion light years away. As a result the light itself has become stretched, which causes it to be shifted more towards the red end of the spectrum – red shifted.

Rik Sargent

FROM THE FORUM

Every month we'll feature a reader's question from our fantastic forum at www.howitworksdaily.com/forum

How does the three-axis gyroscope in the new iPhone 4 work?

Mustafa

A gyroscope uses the principles of conservation of angular momentum in order to determine orientation. You may be more familiar with the mechanical gyroscopes, however there are also electronic gyroscopes. The iPhone 4 uses a chip called a MEMS gyroscope.

Inside the MEMS chip is a plate called the 'proof mass', which vibrates when a drive signal is applied to a set of drive capacitor plates. When a user rotates the phone, the proof mass gets displaced in the X, Y, and Z directions by Coriolis forces. Another type of chip called an ASIC processor records this displacement by use of capacitor plates on the underside of the proof mass.

There are other extremely tiny chips which then do a job of turning this electrical information into a digital signal which is fed into the central processor of the iPhone 4. This data is then used, for example, to turn the steering wheel of a car or to aim a gun in one of the iPhone 4's many videogames.

Rik Sargent

Could the tiger soon be going the way of the dodo?

© claudiogennari

Are there more species being discovered than dying out?

Lisa Sargent

■ The tiger has moved to the top of the at-risk list while the psychedelic frog fish has only just been discovered. Many more species are "discovered" every year around the world than are recorded extinct, but these "new" plants and animals are simply existing species found by humans for the first time, not newly evolved species. In total only around 1.5-2 million species have been described by scientists against estimates of between 10-30 million species currently living on Earth. Around 16,000 species of plant and animal are described for the first time every year.

The current estimated rate of species loss is between 100-1,000 times the background rate calculated from the geological record. This implies that many more species are currently going extinct than are evolving. Currently around 17,000 species are considered to be under threat of extinction; these are mostly vertebrates, as they are much better known.

Dr Bob Bloomfield, IYB-UK & Dr Sandra Knapp, Dep. of Botany

What is biodiversity and why is it important?

Kenneth Hammond

■ Biodiversity refers to the variety of life on Earth. It includes all species from the blue whale to the smallest bacterium, and their genetic (molecular) differences as well. Biodiversity also includes all the variety of habitats where organisms live – ecosystems – such as coral reefs, grasslands and rainforests. Without biodiversity we would have no fresh air or water, no resources for food or medicine, no protection from natural disasters such as floods or those associated with climate change. Biodiversity is life and people are a part of it; our health, wealth and wellbeing depends on keeping global biodiversity healthy.

Dr Bob Bloomfield, IYB-UK & Dr Sandra Knapp, Dep. of Botany

HOW IT WORKS EXPERTS

Dr Robert Bloomfield
Director IYB-UK/Head of Innovation and Special Projects, Natural History Museum

Bob is Head of Innovation and Special Projects at the Natural History Museum where he has delivered Darwin200 and is now directing IYB-UK during 2010. With a PhD in Genetics, Bob has pursued a career in science and public engagement, leading major science communication projects. In 2002 Bob was awarded a NESTA Dream Time Fellowship which he ultimately used to retrace the first voyage of Captain James Cook.

What's on?

Carole Jahme is Biodiverse!

■ 6-30 August ■ Charges apply ■ Edinburgh Festival Fringe at the Zoo Southside, Cabaret Bar

A one-hour black comedy for adults on biodiversity and human evolution. Carole Jahme is a 'humanzee' (half-human-half-chimpanzee) unable to find a mate due to habitat loss. The audience will be encouraged to regress to their primordial origins, to get in touch with the ape inside.

With a little theatrical trickery, a gorilla and an Australopithecine will be brought to life as we ponder biogenetic advances that could bring our ape-man ancestors back.

Canoe Safari

■ 14-18 August ■ £25 ■ WWT Welney Wetland Centre, Cambridgeshire

Explore the hidden reaches of the WWT Welney reserve by canoe! Led by a professional, experienced canoeist, together with the Welney Reserve manager, see the habitats and hideaways of some of this area's more elusive wildlife. To book, call 0845 409 1303.

What's on?

Batty Night Out

■ 25 and 27 August ■ Free ■ Bog Meadows Nature Reserve, Belfast
Join the Ulster Wildlife Trust's bat expert Robin Moffitt for an illustrated talk and walk to find out more about these creatures. See and hear bats in their natural environment using special detectors, and learn how all those bat-related myths are just plain batty. To book, call 028 4483 0282.

Autumnal Migration in North Kent

■ 10 September ■ £25
■ Elmley RSPB Reserve and Oare Marshes, Kent
The autumn migration season is an unmissable opportunity to come and learn about the UK's waders and migrant birds.

Oare Marshes and the Elmley RSPB reserve sites in Kent are the perfect setting to discover more about these spectacular birds. You can also learn about and observe birds of prey at one of the best sites for them in the UK. Led by Tony Swandale, Warden, together with ornithologist Rob Clements. To book, call Kent Wildlife Trust on 01622 662012.

Blue Ribbon Village at the Mayor's Thames Festival

■ 11 and 12 September ■ Free
■ Potters Field Park and the Riverside Walkway between City Hall and Tower Bridge, London
Blue Ribbon Village is the interactive river and environment zone at the Mayor's Thames Festival. The Village features information stalls and activities provided by a wide range of organisations promoting biodiversity within urban, rural and marine environments. From bee keeping to pond-dipping, wild-flower cooking to amphibian and reptile conservation there's lots to learn and try your hand at.

An eclectic programme on the Blue Ribbon Bandstand, featuring brass bands, folk musicians and choirs will provide a musical backdrop to this event.

Why are cane toads such a problem in Australia?

Vicky Plummer

■ The cane toad (Bufo marinu), is a large, terrestrial toad native to Central and South America. It was introduced to Australia by the sugar cane industry in 1935 in an attempt to control beetles that were damaging the sugar cane. This was done against the recommendations of many scientists at the time and was subsequently proven to have been exceedingly ill-judged.

Thousands of toads were released without any scientific testing on the breadth of their diet, and they not only failed to control the beetle, but turned their carnivorous attention to any creature that was small enough to be swallowed – becoming a significant problem themselves. Without their own natural enemies and thanks to some formidable defences, they were able to spread rapidly.

Although it was carried out in the name of biological control, today's practitioners consider this release to have been a highly irresponsible act. With today's stringent regulation and extensive scientific testing, the introduction of the cane toad would not be allowed.

Societal values have also changed; we now value native species' biodiversity far more highly than perhaps ever before. In fact, biological control today is often used to increase species biodiversity.

Dr Dick Shaw, principal investigator, CABI

Why is the bee population declining?

Alex Murphy

■ This depends on the species of bee. The honeybee has been subject to several pests, including varroa mite, hive beetle and a plethora of viral diseases which all affect the health and productivity of the hive. There have also been many media articles concerning colony collapse disorder (CCD), which is likely to be due to a combination of factors including bee stress and the use of insecticides.

Several species of bumblebee are also in decline and the principle factor causing this is habitat loss. The species most affected are those which inhabit field margins, chalk downland or other specialist habitats. We don't know enough about their specific habitat requirements to effectively conserve many of these.

Stuart Hine, centre manager – Angela Marmont Centre for UK Biodiversity

How come some mammals lay eggs?

Val Grimes

■ Mammals such as the duck-billed platypus continue to lay eggs, but they actually never really stopped.

Mammals began to evolve from egg-laying reptiles around 200 million years ago. An example of an early mammal-like reptile is Thrinaxodon. About 180 million years ago the other mammals branched off and essentially gave up laying eggs – they became the marsupials (such as kangaroos) and the placental mammals (such as cats, bats and humans). Incidentally, some reptiles have also given up laying eggs – for example boas and a number of lizards. But a few mammals have carried on laying eggs just like their reptile ancestors.

These 'monotremes' (meaning 'one hole' – they have a multipurpose hole through which they defecate, urinate and reproduce, just like snakes and birds) are now represented by just five species: the duck-billed platypus and four types of echidnas (spiny anteaters). Their eggs are rather leathery and the females don't have nipples, but 'sweat' milk instead from a patch on their belly. In fact it may be that milk evolved from sweat. As for why they never gave up egg-laying; well, if nature comes up with a design that works for the places and conditions where an animal lives, why change?

Simon Garrett, head of learning, Bristol Zoo Gardens

The introduction of the cane toad proved to be a huge error

What is the most poisonous plant?

Jimmy Thomas

■ Many plants are poisonous to varying different degrees, though perhaps water hemlock's root would be the most likely to kill a human, a small mouthful being sufficient. Many plants of the genus Aconitum sp. are common garden plants – such as Monkshood and Wolfsbane – and prolonged handling can cause death.

The family Solanaceae contains belladonna, much loved by Cleopatra to dilate her pupils but nonetheless deadly; also Datura a popular bedding plant. The castor oil plant carries the *Guinness Book Of World Records* title as the world's most poisonous plant, used recently to assassinate a Bulgarian dissident. Alpha-Amanitin is found in several members of the Amanita genus of mushrooms, most notably the Death cap and the Destroying Angel. They will cause rapid liver failure and death, after a day with no symptoms.

Peter Brownless, garden supervisor nursery – Royal Botanic Garden, Edinburgh

What's the difference between fruits and berries?

Kay Leeming

■ In general terms a fruit is the result of a flower being fertilised and flesh growing around to protect and help spread the seeds. Most people think of apples and pears when they refer to fruits. Berries are also fruits but they have a juicy pulp surrounding the seed or seeds. Blueberries, black, red and white currants are true berries as the pulp surrounds the seeds. Raspberries, blackberries and similar fruits are known as "aggregate fruits" as they are made up of lots of little fruits.

Strawberries are slightly different as it is actually a part of the flower that becomes the berry and the seeds are situated on the skin of this fruit so that is why the "pips" are on the outside.

Guy Barter, chief horticultural advisor – Royal Horticultural Society

What's on?

The Secret Life Of Seals

■ 14 September ■ Free ■ Meet at Driftwood Spa, Trevaunance Cove, St Agnes

Join in with the Cornwall Wildlife Trust for an exciting illustrated talk from renowned seal expert Sue Sayer from the Cornwall Seal Group. Participants can learn all about these beautiful creatures with which we share the Cornish coastline. Come along and you will also discover what you can do to help and protect these remarkable animals.

Galapagos Day

■ 15 September ■ £30 ■ Royal Geographical Society, 1 Kensington Gore, London, SW7

Galapagos Day is the annual event organised by the Galapagos Conservation Trust (GCT), the UK's one and only charity dedicated to raising not only funds, but also awareness of these incredible islands.

The guest panel of speakers includes travel writer and conservationist Stanley Johnson (father of the London mayor); H E the Ambassador of Ecuador, Mrs Ana Albán Mora; the great great granddaughter of Charles Darwin, Dr Sarah Darwin; and executive director of the Charles Darwin Foundation in Galapagos, Dr J Gabriel Lopez.

The esteemed panel will talk about their different experiences of one of the world's most iconic natural wonders and their thoughts on the islands' future. To book, call 020 7629 5049.

Visit the website

For more information on these events and more across the UK visit www.biodiversityislife.net

This website is the UK partnership supporting IYB. It's a great source of news and events concerning biodiversity and the environment.

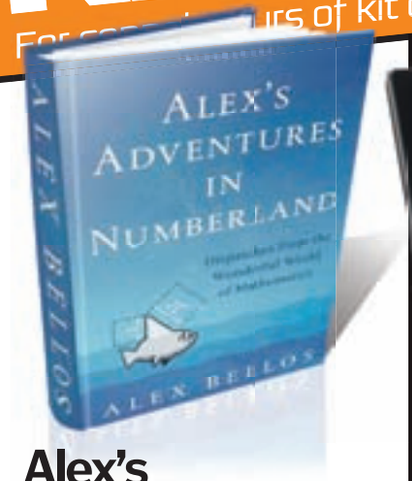
IYB-UK is made up of over 400 major organisations, charities, universities, businesses, schools, museums and arts practitioners. Dr Robert Bloomfield, the director of International Year of Biodiversity in the UK, will be marshalling a range of experts from across the partnership to answer your questions.

2010 has been declared the International Year of Biodiversity (IYB) by the United Nations.

THE HOW IT WORKS KNOWLEDGE

For sc... urs of kit and savants of stuff

Games • Books • Gadgets • Toys

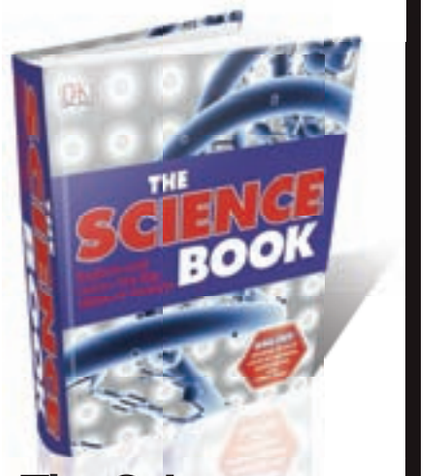


Alex's Adventures In Numberland

Price: £18.99 / $39.99
ISBN: 978-0-7475-9716-2

Mathematics, the foundation of science and with applications in every facet of life, has proven an enduring fascination for author Alex Bellos, who takes the reader along the scenic route through a quagmire of quadratics, integers and equations to beguile them with the beauty and power of numbers.

Verdict: ✪✪✪✪



The Science Book

Price: £19.99 / $24.99
ISBN: 978-1-40535-413-4

Dress academic subjects the right way and kids will lap it up. That's the idea behind *The Science Book*, it seems. Illustrated with diagrams, photos and bursting with facts, DK has furnished this children's encyclopedia with a companion website that hosts fascinating interactive Flash animations and quizzes. It's a potent learning combination.

Verdict: ✪✪✪✪

Like Mighty Mouse, this netbook is small but powerful

Alienware M11x

Price: £859.99 / $949.99
Get it from: www.alienware.com

ALIENWARE HAS SERIOUS pedigree in creating gaming laptops, with its M15x and M17x variants prized among gamers at LAN parties worldwide. Powerful, stylish and desirable, historically their only weakness has been their size and weight when being transported and heat output when running full whack, leading to them being seen by gamers as more of replacement desktops rather than portable companions to be used on long train rides. Its new baby variant however – the M11x is a netbook – aims to change all that, providing good gaming performance but in a unit with less weight and a more portable, 11-inch screen.

So, the stats. The M11x is fitted with a 720p HD 11.6" (40cm) widescreen display, which has a native resolution of 1366x768. Partnering this screen, our model – various models can be customised at Alienware – was fitted with a Core i5 processor, a GeForce GT335M GPU and 4GB of DDR3 memory, as well as a hefty 500GB SATA hard disc drive. The body of the laptop provided a mic jack, three USB ports, two headphone jacks, D-Sub port, HDMI port, DisplayPort, Ethernet port, a four-pin FireWire port and a memory card reader. The weight of the unit was a touch over 4.5lbs. Finally, the keyboard, left and right chassis corners and status lights all were illuminated with Alienware FX, a customisable programme in which users can assign up to 19 colours to these independently.

On test – despite initial reservations – the M11x performed incredibly solidly and before long it was easy to forget that we were testing a netbook and not a full-blown gaming laptop. *Modern Warfare 2*, *Left 4 Dead 2* and even *Crysis* – albeit on medium settings and with a resolution of 1024x768 – played perfectly, with frame rates consistently high and coming in well over our minimum of 25fps. Battery life surprised us too, with the unit running for over three hours during intensive usage – this, while short of Alienware's optimistic estimates, is superb considering its power and excellent news for any gamer on a long-haul flight. Finally, the Alienware impressed in terms of build quality, with the unit resembling its bigger brothers identically in ergonomic and aesthetic qualities, feeling solid and well made.

Overall then, the Alienware M11x is an excellent piece of kit and any gamer would probably sell their house in order to acquire one. However, its awesome performance comes at a very high price – one for which you could buy a more powerful laptop – and potential buyers should weigh-up how much portability matters before deciding whether to splash out.

Verdict: ✪✪✪✪

Robo Bank

Warning! Warning! My savings are increasing wildly!

Price: £12.99 / $17.99
Get it from: www.amazon.co.uk

IT IS A rule of thumb that if you take any product and then turn it into a robot it automatically gets 100 per cent better. That is the case with the Robo Bank from the Science Museum, which turns the mundane task of saving your hard-earned pennies instead of spending them on sweets, considerably more enjoyable.

Money is inserted into the bank through a slot on the head and each time it is deposited the Robo Bank will display and announce the amount of money you have just inserted. It also counts all the money you put in it and displays your grand total at the push of a button, automatically making adjustments to the figure if you make any withdrawals.

The Robo Bank also acts as a bedside clock and calendar, displaying the time and date on its chest-mounted screen and has a movement sensor that allows him to talk and move his arms when approached. All you need now is that Robo Butler and your *Jetsons* lifestyle will be complete...

Verdict: ★★★★

Casio Exilim EX-H15

Exilim-pary speed and snapshot quality

Price: £186.87 / $279.99
Get it from: www.amazon.co.uk

WITH MEGAPIXEL COUNTS typically in double figures on the average portable digital camera, manufacturers appear to be looking for other features they can use to make their product stand out from the crowd: like the optical zoom on Casio's Exilim EX-H15. At 10x or 24-240mm in standard film gauge, it's miles above the 3x and 5x zoom of its competitors that share the same price bracket. It puts wide angle landscape shots and high quality group portraits well within the reach of the amateur photographer and close to an SLR enthusiast.

The optical zoom is a bonus: with individual photos of up to a 14.1 megapixel resolution and 1280x720 video capture, the EX-H15 can take enormously detailed shots even at minimum zoom. The standout feature for us is the fractional time that this camera takes to auto-focus and take a shot from the moment you press the button, provided by its Exilim engine processor.

It doesn't quite have the response time you'd want for high speedy sports with a minimal window for photographic opportunities, but it puts the competition to shame.

Verdict: ★★★★

Game reviews

Kane & Lynch 2: Dog Days

- **Price: £36.85 / $59.99**
- **Format: X360**

The original *Kane & Lynch* was a big disappointment. Annoying, broken and riddled with bugs, it was a rare misstep for IO Interactive, and one that it has mostly rectified with its successor. Set in Shanghai, *Dog Days* switches the protagonist from Kane to Lynch as he tries to score a big payday and, needless to say, things don't go quite to plan. The action that follows is greatly improved by a new shooting and cover system, as well as a more streamlined user interface and better enemy AI. Oh, and it is violent... very violent.

Verdict: ★★★★

StarCraft II: Wings Of Liberty

HOW IT WORKS EDITOR'S CHOICE AWARD ★★★★★

- **Price: £44.99 / $59.99**
- **Format: PC**

StarCraft II is the sequel to Blizzard's epic science fiction real-time strategy that shames other games that share its genre. Reportedly costing over $100 million – a figure unheard of in the industry – this PC exclusive has the animation, depth of features, compelling story, comprehensive multiplayer and sheer polish that provides value for money well beyond its retail price: an instant classic.

Verdict: ★★★★★

Mafia 2

- **Price: £36.99 / $59.99**
- **Format: PS3**

The original *Mafia* was a sleeper hit when released back in 2002. 2K Czech aims to follow that success with its follow-up *Mafia 2*, a narrative-driven sandbox title that is set ten years after the original. You play Vito Scaletta, a soldier recently returned from WW2, who over the next 30 or so years becomes more and more involved in the criminal underworld. The title is heavily story driven and arguably more adult than the *GTA* franchise in its handling of its violent themes. It is, however, less open – but not altogether restrictive.

Verdict: ★★★★

Metroid: Other M

- **Price: £34.99 / $49.99**
- **Format: Wii**

The *Metroid* franchise gets a lick of paint and radical overhaul here by developers Team Ninja in *Metroid: Other M*, a fast-paced action shooter for Wii. Switching perspective from the FPS nature, *Other M* presents a world that is viewed in both third-person and first-person perspectives, and one in which Samus – the protagonist – must negotiate hard to survive in. Overall, this is *Metroid* of old but with more style, a quicker pace, and a fresh new perspective.

Verdict: ★★★★

THE HOW IT WORKS KNOWLEDGE

For connoisseurs of kit and savants of stuff

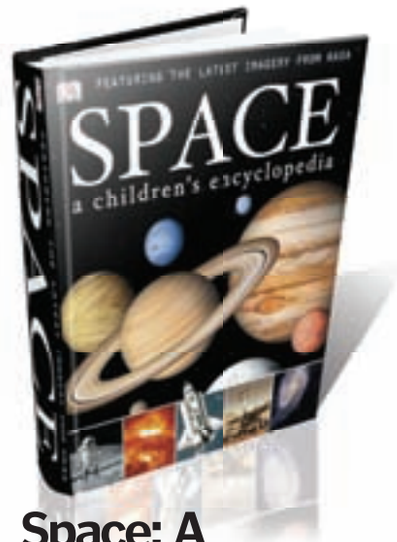
DVDs/Blu-ray • Books • Gadgets • Toys

History Of Western Philosophy

Price: £15.99 / $24.99
ISBN: 978-0-41532-505-9

First published in 1946, the *History Of Western Philosophy* by Bertrand Russell remains unchallenged to this day as the ultimate introduction to western philosophy. Witty, cogent and comprehensive, this is one of the most important philosophical works of all time and is easy to recommend.

Verdict: ✿✿✿✿✿



Space: A Children's Encyclopaedia

Price: £17.99 / $25.99
ISBN: 978-1-40535-375-5

A highly approachable title aimed at younger astronomers keen to learn more about our solar system and other space phenomena. *Space: A Children's Encyclopedia* will teach children everything they need to know in an entertaining fashion.

Verdict: ✿✿✿✿

Astronomical performance

Astro A30 Headset and Audio System

Price: £149.95 / $199.99
Get it from: www.astrogaming.co.uk

FOLLOWING ON FROM Astro's earlier celebrated A40 Headset and Audio System that was specifically tailored for pro gamers, Astro has now released a smaller, multimedia variant aimed at a wider market. The A30 Audio System couples the LAN functionality and Dolby headphone technology of the A40's MixAmp – which is compatible with both Xbox 360 and PS3 – with the new supra-aural "on-ear" cushion design of the A30 headset.

On test the A30 was very impressive, offering superb build quality and comfort, with rich bass tones and vivid mid and high tones. Its frequency response was also excellent and felt balanced across a range of media, be that watching films on our Rock laptop, listening to music on an iPhone, or playing *Modern Warfare 2* hooked up to the MixAmp.

Overall, this is a great package – although if you don't own a PS3 or Xbox 360 then the MixAmp isn't really necessary – that while providing excellent gaming audio feedback, also broadens its potential usage to a number of other forms of media and, arguably, outshines the A40 in terms of overall sound quality.

Verdict: ✿✿✿✿

Zapi Toothbrush Sanitiser

Stop hogging the bathroom

Price: £24.95 / $29.95
Get it from: www.cutebitz.com

THE THREAT OF that nasty H1N1 swine flu virus is still hanging around: no one you know can honestly say they ever caught it, but around the time that the TV and newspapers buzzed with this unfettered "epidemic", several of your friends and relatives felt slightly off-colour – and that surely can't be a coincidence, can it?

The Zapi Toothbrush Sanitiser is one of many products that still capitalises on the paranoia surrounding swine flu. And while we'd rather not help propagate the idea that the bug is still at large, Zapi does put a compelling case forward for this fancy ninja-shaped toothbrush holder.

Bathrooms are full of bacteria and if you're going to clean your teeth, why would you introduce even more into your mouth? This sanitiser holds the toothbrush in place as it blasts the head with germ-killing UV light for seven minutes, eliminating 99.9 per cent of all bacteria including H1N1, before it switches itself off. And if peace of mind is all you want, we suppose it's worth it at this price.

Verdict: ✿✿✿

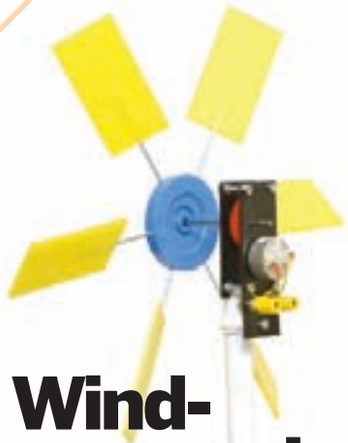
Solargorilla

The monkey's got the juice

Price: £140.00 / $259.99
Get it from: www.powertraveller.com

TECHNICALLY, THE SUN is a finite source of energy, but as long as we're measuring our daily routine in hours, the juice Powertraveller's portable solar panel chargers provide will always be free. The Solargorilla is the hefty silverback of the range, providing an alternate charging option for laptops under 40 watts as well as a host of smaller electronic devices, including mobile phones and portable games devices. Overall, at a lightweight 820g the Solargorilla makes an ideal camping solution and excellent travel partner for the adventurous type.

Verdict: ✿✿✿✿



Wind-powered turbine

It won't blow you away

Price: £19.98 / $29.99
Get it from: www.mutr.co.uk

This modest plastic turbine from Middlesex University comes with rotor blades and a small generator that produces a low wattage of electricity whenever the rotors spin.

Construction looks simple on paper but younger kids may need a little help with some of the trickier parts of the set up. Once built, the result is as satisfying as ever though, and the turbine will easily light an LED or low-power device in a steady breeze.

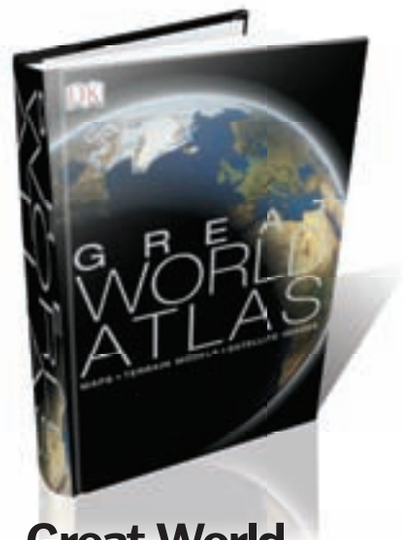
Verdict: ✿✿✿

Animal Life

Price: £30.00 / $35.99
ISBN: 978-1-40532-215-7

DK books continue their excellent track record of providing concise and image-led titles with this excellent exploration of the extraordinary behaviour of animals in their own environments. Mammals, birds, reptiles, amphibians, fish and invertebrates are all covered in detail by author Charlotte Uhlenbroek, from behavioural traits and organisation, to courtship rituals and hunting.

Verdict: ✿✿✿✿



Great World Atlas

Price: £75.00 / $115.00
ISBN: 978-1-40532-985-9

The *Great World Atlas* provides an awesome detailing of the planet on which we live. Providing unparalleled cloud-free satellite images, stunning terrain models and high-definition large-scale maps, this definitive title produces a complete picture of the Earth as it is now and is an invaluable resource for research, reference and edutainment.

Verdict: ✿✿✿✿

Chumby Classic

Love it… what's it for, again?

Price: £139.99 / $149.95
Get it from: www.chumby.com

YOU HAVE TO admire the thought that's gone into the marketing behind this web player, even if the actual product feels redundant in a generation of highly capable, multimedia phones. With a soft, padded leather chassis and a warm introduction from the anthropomorphised company directors on the 3.5-inch colour touch screen, it has a similar ethos to an Apple product: you don't really need it, but you want one anyway.

The Chumby Classic is a Wi-Fi device that grabs content off the internet on demand via the widget you choose to personalise it with, and stream it onto the touch screen. Facebook, Twitter, podcasts, YouTube, national news, the weather in Antarctica: once you've activated your Chumby and picked the appropriate widgets, as long as there's a viable wireless connection in the area, it's all within your grasp.

It includes an accelerometer for tilt-sensitive applications, a two-watt speaker of surprisingly high standard, headphone jack and two USB 2.0 ports. The number and quality of the features makes the Chumby great value for money and perhaps we're being short-sighted here, but we've no idea what we'd use it for. It would make a very nice alarm clock but tethered to a mains power supply, it's not even portable and there's nothing the Chumby does that a modern cell phone can't do for the same price.

Verdict: ✿✿✿

GROUP TEST
Network media players

Wirelessly store and stream HD movies with ease

Netgear Digital Entertainer Elite

Price: £229 / $299

Get it from: www.play.com

Netgear's entrant is perfect for the newbie. What it lacks in file support it more than makes up for through an insanely simple and well designed front-end that's got some stunning features. Setting up this 500GB, Wi-Fi-enabled model couldn't be easier either – Netgear walks you through the process of adding media, sorting out network shares and even finds your local town so it can keep you up to date with the weather. Sadly, we found performance a little flaky with a couple of crashes within the first two hours on test and it couldn't cope with some of the same files as its competitors.

Verdict: ✿✿✿

Pros:
- Beautiful chassis
- Easy set-up
- Stunning extra features

Cons:
- Horrible remote
- Average file support
- Software's a bit flaky

AC Ryan Playon! HD Network Media Player

Price: £160 / $249

Get it from: www.amazon.co.uk

With support for a wide range of file types right up to 1080p MKVs, the Playon!HD starts strong and is one of the best looking units on test. Bundled with a 500GB hard drive (it's also available with 1TB or no disc at all), you'll be able to play back all your favourite home media, while downloading via its built-in bit torrent client in the background. You can also hook it up to your network via ethernet or an additional extra Wi-Fi add-on. Sadly, the network playback requires too much remote waggling (even once set-up), so if you plan to play from your PC or central storage it's not the best choice.

Verdict: ✿✿✿

Pros:
- Great looking unit
- Good file support
- Affordable

Cons:
- Ugly remote
- Unfriendly network play
- Basic interface

HOW IT WORKS GROUP TEST WINNER

Popcorn Hour C-200 Network Media Player

Price: £279 / $399

Get it from: www.ripcaster.co.uk

It's the most expensive on test for a reason. It boasts the widest range of file types bar none, and will cope with the highest bit rate, most diverse file type and the back-lit remote control even works through walls. You'll need to install your own hard drive, but assuming you're playing across a network you can rip out the hard drive rack and replace it with a Blu-ray player. That's right, stick a PC Blu-ray drive in the bay (from £50) and you'll be in home HD nirvana. There's still room for a 2.5" hard drive too. Amazing.

Verdict: ✿✿✿✿✿

Pros:
- Amazing file support
- Convenient network play
- Brilliant remote

Cons:
- Big and bulky chassis
- Noisy HD playback
- Hard to read LCD display

HOW TO MAKE
A modded Nerf Maverick

DISCLAIMER!
Modifying a Nerf Maverick, while relatively simple, will void your warranty on the toy and will increase power to propelled darts. Under no circumstances is it advisable to fire at human faces with a Nerf gun – modded or unmodded – and Imagine Publishing and its staff cannot be held responsible for injury caused to the operator or any third-party as result of modifying or firing a Nerf product.

A modded Ner

War. War never changes. Especially the foam-based variety, which thanks to Nerf's continuous arsenal growth, can lead to home and office-based carnage the likes of which would make Sun Tzu blush. Indeed, only the other day, How It Works magazine lost its senior sub editor Jon in an all-out assault by the human resources department in a bid to snaffle the last of the week's supply of jam-filled doughnuts. It was horrible… in the end there was jam everywhere.

Luckily, weapons tech is a special forte here at How It Works and so this month we decided to print an extract from our best-selling title *The Art Of Nerf*, in which we show you how to modify a Nerf Maverick handgun with a few simple household tools to provide more power and a quicker reload time.

Construction materials:

- 1 x Nerf Maverick
- 1 x Craft knife / scalpel
- 1 x File
- 4 x Penny coins
- 1 x Screwdriver
- 1 x Blu Tack pack
- 1 x Paint brushes (optional)
- 1 x Forked hammer

All construction materials can be acquired at Maplins. Nerf Mavericks can be bought at all good toy stores.

Increase power and reload time with a couple of handy hacks

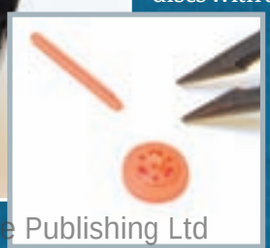
Step 01

1. Take your Maverick apart by carefully unscrewing the eight body screws (one is hidden under the cocking mechanism and becomes accessible once taken off) and the three smaller cocking mechanism screws, before then lifting the top part of the gun and mechanism off to reveal the gun's innards (A). Quickly, just in case you lose any pieces, make a note of where each part fits. Now remove the barrel component by lifting it out of the body – just wriggle it a bit and it will come out – as well as these pieces (B). Nothing else should come free from the body.

Step 02

2. Firstly we will complete the barrel mod, which will allow the loading chamber to snap all the way out of the body for easy insertion of darts. Take the barrel and with your forked hammer prise the grey plastic piece at the orange-tipped end of the unit away (it requires a bit of force but not much). It will separate once free into three pieces: metal pole with orange cap, grey plastic piece, and circular orange cap. Take the grey piece and file away the small curved knob that is positioned here on it (A). With the lower half of the gun's main body do the same filing away job on this yellow knob as well (B).

Step 03



3. Now for more power; this will require three separate hacks. Take the remaining barrel structure and unscrew the three small screws here (A) and take the black lid off the top. There appears to be lots of stuff in here at first (six springs, six three-feet orange caps and six orange plastic discs with a central column emanating from them), however don't worry as you can bin the springs and tri-podded caps as they are only there to slow the darts down. Once binned, take the six orange caps and cut the central columns off close to the base, leaving just the discs (B). Now replace the discs back in the six chambers (stub downwards) and screw the lid back on.

rf Maverick

Step 04

4. The barrel structure is now modified for extra power and Russian roulette-style loading accessibility. You can re-insert the metal rod through the barrel and attach the grey piece and orange cap as before. The orange cap is best repositioned by just hammering it back onto the end (A). Your barrel should now be complete again, however the grey plastic piece should be knobless. You can put the barrel to the side.

Step 05

5. Now take this piece of your gun (A) – it is the air chamber, where the gun's air is gathered and released from when you cock and fire it – and pull the end out. Notice how when you look down the inner cylinder the oval-shaped hole covers only roughly half the circumference? Well, that half of the chamber needs to be filled with Blu-Tack, as in doing so you will decrease the volume in which the same amount of air will be compressed into, thereby increasing the force of its release when the trigger is pressed. The best way to do this is to roll a tube of Blu-Tack the same length as the cylinder, insert it, and then flatten out the surfaces so it snugly fits the curvature (of course, make sure the oval-shaped hole is completely unrestricted) (B).

Step 06

6. Finally, reassemble your gun so it is how it was when you first took the top part of the gun's body off and then, taking your four penny coins, position them like this (A) behind the rear end of the spring. This will reduce the amount of room the spring has to coil and, consequently, make it more compressed when you cock the gun, increasing power. You can now place the top part of the gun's body and cocking mechanism back on and re-apply all your screws. You should now have what looks like a regular Nerf Maverick, however the barrel will now slide out fully from the side and the combination of barrel, air chamber and spring power hacks will mean it fires further and flatter than a stock model.

Step 07 Completed!

7. Congratulations! You have modded your very own Maverick. Now go and humiliate your friends by peppering them with darts from greater distance, while reloading faster and distinctly cooler.

The stats – before and after:

To test the benefits of our mods, we recorded the flight distance of our Nerf darts both before and after our tinkering. During the test we fired three rounds each time at a level trajectory and then took an average distance. Firing down Imagine Tower's patented Endless Hallway, before modification the Nerf Maverick propelled its darts an average of 22 feet. However, we knew we could squeeze more performance out of it for no extra cost. Post modification, the Nerf propelled its darts over 35 feet, a whopping increase of 63 per cent!

Distance before mod:
22ft

Distance after mod:
35ft

Increase in power...
63%

GET INVOLVED!

Have you performed a different mod that you want to show off? Then why not send your pictures to howitworks@imagine-publishing.co.uk and we'll show it to the world!

HOW IT WORKS INBOX

Feed your mind. Speak your mind

Focusing on the few positives around the oil spill

Courtesy of International Bird Rescue Research Center

Letter Of The Month

More green issues

I've been buying **How It Works** since issue 4 and enjoyed each issue immensely. The magazine offers a great balance between bite-sized articles and longer features, which makes it great for dipping into or for longer reading sessions too. I thought issue 10 was great and although issue 7 with the Brian Cox interview remains my favourite, the magazine seems to go from strength to strength with each issue. I do, however, have one complaint, which I'd like to raise now.

The oil spill article was very informative to read but it did not touch upon the environmental havoc that the recent events in the Gulf of Mexico will cause for many years to come. In the environment section we had a great piece on how oil is formed, but that again neglected to tell us about the environmental damage that drilling for oil often does to the surrounding areas. In fact, I would go further and state that for a section called 'environment' very few environmental issues are actually tackled. So come on, **How It Works**, start telling us about the green issues that affect our world and what we can do to solve them.

Carl Dexter

HIW: If you accuse us of shying away from controversial subjects in How It Works you'd be dead right. And for good reason. Debating controversial topics simply isn't within the editorial remit of the magazine.

When How It Works was born it was decided that our mission was to explain how things work and to inspire a sense of wonder in the world around us. In the case of the oil spill we decided this mission statement was best served by focusing on the positive aspects of the technology that attempts to fix some of the damage done to the environment rather than on the damage itself.

There's also good reason why we don't cover more environmental issues in the environment section. These sorts of topics are often the subject of competing theories and point/counterpoint debate (take global warming for instance), and so it becomes hard for us to give a definitive answer to 'how' it works, which – as you'll have gathered by now – is what this mag is all about.

Get in touch!

If you've enjoyed this issue of **How It Works**, or have any comments or ideas you'd like to see in a future edition, why not get involved and let us know what you think. There are several easy ways to get in touch...

Console yourselves

Please could you explain how game consoles work for the young readers? People play games on them, watch DVDs, listen to music and even save family albums but don't know how these things work. I have been curious how game consoles work for a while and have asked a lot of people but never understood their descriptions at all, so I thought that you could explain it better and with more detail. Love your magazine.

Adam

Respect the Union

I like the magazine, but would like to point out that in 'This Month in History' contents page 68, issue 9, Germany's campaign was against the British and not just the English. Please respect the other countries in the Union. Thanks for not hiding the contribution of the Polish in the Battle of Britain.

Ed Stuart

No imperial!

Seen your magazine on the shelf and bought it on impulse. I was a little disappointed with some of the writing style (a bit too dumbed down for my liking), however the content was generally quite good. What did irritate me hugely was the constant use of imperial measurements; miles per hour, Fahrenheit, gallons etc. Metric units are universally used in scientific work and it is the official system of measurement for the UK (and 99 per cent of the world). If you want to be taken seriously as a scientific magazine then your conversion to metric is long overdue. Please don't mention both imperial and metric – it's both condescending and unnecessary.

Val

Index please

Now that **How It Works** is building up to be a unique reference work, would it be possible to publish a cumulative index every so often? Thanks.

George Green

Hello MotoGP

I'm a big fan of your magazine! In an earlier issue you had an article on the technology behind a Formula One car. Being a motorcyclist, I would like to suggest an article on the current MotoGP motorcycles. From gyroscopes, counter-steering, dual-compound tyres, advanced electronics to the position of the rider's body there is a wealth of interesting information. Keep up the good work.

Dean Walker

Can't get enough of How It Works?

Signing up to the forum couldn't be easier, just take a few minutes to register and then start sharing your questions and comments. The How It Works staff will be on hand to answer your questions and initiate debate.

www.howitworksdaily.com/forum

How to contact us

Facebook: search for 'How It Works'

Email: howitworks@imagine-publishing.co.uk

Twitter: http://twitter.com/HowItWorksmag

Web: www.howitworksdaily.com

Engineer seeks others

I came across your magazine purely by chance and was very impressed with the amount of detail and range of articles it contained. I actually worked on the Martin Jetpack for several years, mostly while it was a secret project, and I am very pleased to see people now taking an interest in it.

Having recently moved to England, I was wondering if you know of any meetings or foundations for engineering innovation. I'm partly looking for work, but mostly just want to meet like-minded people in engineering and technology. Thanks for your help.

Edward Fletcher

HIW: Hi Edward. What a great project the Martin Jetpack is, and it must have been great working on it. The article caused quite a buzz in our office, with people wanting to know more about it. With regard to your request for active groups of like-minded engineers, we would like to throw it out to our readers. If anyone knows of any such groups, please get in touch either via email or our forum on the How It Works Daily website.

These pilots are British, not English

"Apple may be the trendy, cool choice but there are real alternatives for those who don't want to follow the crowd"

Damn, we'd love a hands-on review

How do Chelsea Pensioners work?

Still reading and enjoying your mag a lot. Can't wait for the next issue (again). I have another question. What is a Chelsea Pensioner? I know they are men who fought hard for this country one way or another but what did they do and why are they often seen at Royal/military events? Thanks.

Martin Smith

HIW: Hi Martin. We get sack-loads of requests and questions from readers with their ideas for what they would like us to cover in the mag, but this has to rank among the weirdest we have had. You know How It Works is a science and technology mag, right?

Apple do NOT rule the world!

I was disappointed to see yet another huge feature given over to an Apple product in your last issue. What with this article and the previous one on the iPad – along with the head-to-head against Android – I was left wondering if there was some Apple bias going on. What about the HTC Desire, arguably the only rival to the iPhone and viewed by many as a far superior phone to the Nexus One? Will you ever feature this excellent phone or has it been deliberately ignored? I hope not. Apple may be the trendy cool choice but there are real alternatives for those who don't actually want to simply follow the crowd.

Thommo

HOW IT WORKS

Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.howitworksdaily.com

Magazine team

Editor in Chief Dave Harfield
dave.harfield@imagine-publishing.co.uk
☎ 01202 586229

Deputy Editor Helen Laidlaw
helen.laidlaw@imagine-publishing.co.uk
☎ 01202 586215

Staff Writer Rob Jones
Art Editor Duncan Crook
Assistant Designer Jonathan Wells
Senior Sub Editor Jon White
Head of Design Ross Andrews

Contributors
Richard Aucock, Russell Barnes, Aneel Bhangu, Ben Biggs Shanna Freeman, Tom Harris, Bridget McDermott, Shaun McGill, Nick Parkins, Vivienne Raper, Dave Roos, Alasdair Stuart, Luis Villazon, Nigel Watson, Tim Wogan

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Advertising
Digital or printed media packs are available on request.

Account Manager Nathalie Stainer
☎ 01202 586431
nathalie.stainer@imagine-publishing.co.uk

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities.

International Manager Cathy Blackman
☎ +44 (0) 1202 586401
licensing@imagine-publishing.co.uk

Subscriptions
Subscriptions Manager Lucy Nash
subscriptions@imagine-publishing.co.uk

For all subscription enquiries
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Overseas +44 1795 414779
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Circulation
Circulation & Export Manager Darren Pearce
☎ 01202 586200

Production
Production Director Jane Hawkins
☎ 01202 586200

Founders
Managing Director Damian Butt
Finance Director Steven Boyd
Creative Director Mark Kendrick

Printing & Distribution
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